PILOT MONITORING PROGRAM SUMMARY AND RECOMMENDATIONS FOR THE LONG-TERM MONITORING PROGRAM

Monitoring Study Group Report
to the
State Board of Forestry

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Sacramento, California
January 1997

EXECUTIVE SUMMARY

In April 1993, the Monitoring Study Group (MSG) submitted to the State Board of Forestry (BOF) a report entitled, "Assessing The Effectiveness of California's Forest Practice Rules in Protecting Water Quality: Recommendations for a Pilot Monitoring Project and a Longer Term Assessment Program" (MSG, 1993). MSG (1993) recommended establishment of a Long Term Monitoring Program (LTMP) intended to do the following:

- o Provide an ongoing assessment of the effectiveness of the Forest Practice Rules (Rules), as implemented, in protecting the most sensitive beneficial uses of water (i.e., coldwater fisheries and domestic water supplies) through implementation monitoring, effectiveness monitoring, and project monitoring.

- o Provide the results to BOF and the public in a timely manner to contribute effectively to BOF's program for reviewing and, where necessary, strengthening the Rules' performance as best management practices (BMPs).

MSG (1993) also recommended that a Pilot Monitoring Program (PMP) be conducted prior to initiation of the LTMP to provide a practical, small-scale, short-duration test of several critical aspects of the subsequent LTMP. Accordingly, MSG initiated the PMP. It was conducted primarily between June 1993 and December 1994 by staff of the California Department of Forestry and Fire Protection (CDF), California Department of Fish and Game (DFG), the State Water Resources Control Board (SWRCB), the California Regional Water Quality Control Board (RWQCB), North Coast Region, the California Department of Conservation, Division of Mines and Geology (DMG); and by Dr. Andrea Tuttle, a consultant. Other CDF contracts provided ancillary support for the effort (See Appendix).

The PMP's goals included the following:

1. To help ensure that the quality of LTMP monitoring data would be high enough to support LTMP objectives by developing and testing training programs, field reference materials, forms, and instructions, and quality assurance (QA) and quality control (QC) protocols.

2. To help ensure that LTMP results would be reproducible, repeatable, reliable, and consistent by developing a standardized "toolbox" of monitoring parameters and protocols whose utility had been tested and validated by the State agencies and a set of related QA/QC protocols.

3. To help ensure that related data management systems could meet LTMP objectives.

4. To help minimize midstream changes in the LTMP monitoring, QA/QC, and data management approaches that could preclude statistical comparisons between earlier and later LTMP data.

5. To give managers reliable information regarding the funding, time commitments, and resources needed to establish and maintain an LTMP.

6. To help determine the reasonableness of the proposed LTMP objectives and the feasibility of achieving them.

Because of its limited scope and duration, the PMP was not designed to test any of the following:

1. The status of or changes in watershed conditions or cumulative watershed effects.

2. The status of or changes in stream reach conditions or instream effects of a timber operation.

3. The degree of implementation or effectiveness of any Rule provision or of any part of the Process by which the Rules are administered.

4. Compliance with water quality requirements.

The following tasks were carried out during the PMP:

1. Monitoring parameters and protocols that appeared likely to be widely useful for implementation monitoring, effectiveness monitoring, and instream monitoring were selected for testing.

2. Target watersheds and timber operations were selected based on their suitability for testing those parameters and protocols.

3. Training curricula and programs; related field reference materials, forms, and instructions; and QA/QC programs for three kinds of monitoring were developed, implemented, evaluated, and refined.

4. Trained personnel carried out the monitoring protocols and parameters at the selected timber operations.

5. Supervisors and managers carried out their QA/QC responsibilities as necessary.

6. The geology and relative slope stability of some watersheds was mapped to provide a context for the implementation and testing of the monitoring parameters and protocols.

7. Data management systems were developed for all three types of monitoring data; the instream component data management system was implemented, used to analyze the data, and evaluated.

8. An external scientific review of the PMP design and efforts was conducted.

The PMP had two major components: an instream component and a hillslope component that included implementation and effectiveness monitoring. The sites for PMP field work were restricted to closed, completed timber operations that had been conducted under the current set of watercourse and lake protection Rules and had been through at least one winter season since operations were completed. Most of the sites were in the watersheds of the Mokelumne River in the central Sierra Nevada and, in the Northern Coast Ranges, the Gualala River watershed and Noyo River/Ten Mile River area. Finding enough suitable sites was very difficult. About one third of the candidate timber operations were suitable for the hillslope component; less than one sixth were suitable for the instream component. CDF Timber Harvesting Plan (THP) information usually had to be supplemented with landowner information to accurately determine timber operation suitability for either component, and a field check was always needed to determine stream suitability for the instream component. Very few candidate timber operations had stream reaches with the characteristics needed to meaningfully implement the sediment-related instream monitoring parameters. Even fewer had a reach that would have been suitable as a control stream reach. The set of suitable timber operations was too small to provide a meaningful test for either random selection (to reduce bias) or risk-based stratified random selection (to ensure adequate testing of monitoring procedures for Rule provisions applicable to critical sites).

The instream component implemented and tested three parameters related to sediment. The D_{50} parameter is the mean diameter of riffle gravels. It is the most objective of the sediment-related parameters; the results appear consistent by year, by stream reach, and with other parameters. The Riffle Armor Stability Index is more subjective and the results are not as consistent. Both are easy to use and fairly widely applicable. The V* parameter is an index of pool filling by annually mobile fine sediment. It is more difficult to use, the necessary stream conditions limit its applicability, and the results showed many inexplicable inconsistencies.

Macro-invertebrates were sampled, taxonomic classification was performed by the DFG bioassessment laboratory, and several bioassessment metrics and indices were applied. Of these, EPT Index (i.e., total number of taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera), diversity index, and taxa richness appear to be the most likely to be useful in forest situations. Use of the biotic index (a measure or organic pollutants) and dominant taxa (which has high variability) is questionable. Macro-invertebrate sampling was conducted quickly and consistently using DFG's California Stream Bioassessment Procedure (the nearest thing to a standard procedure in the State). The technique appears to be promising.

Stream temperature was measured using Hobo™ recording units, hand held electronic sensors, and hand held thermometers. Where single measurements are adequate or repeated site visits are acceptable, hand held max-min thermometers may be the most reliable and cost-effective instruments. Temperature was easily measured in most stream reaches. It can be used effectively if the monitoring objective is carefully defined and there is adequate recognition of variations in stream hydrology and life cycle needs of aquatic species.

The instream component established and implemented a rigorous QA/QC program to protect the integrity of its quantitative data. The program caught many, but not all, data errors and omissions before they caused significant costs, delays, and inefficiencies.

The instream component implemented a data management system, thereby providing a test of both the monitoring data and the system. The system appears effective and efficient in providing useful queries, analyses, and reports from the instream data. Both the instream and hillslope data bases should incorporate and be effectively linked through Global Positioning System (GPS) and Geographic Information System (GIS) technology.

The PMP hillslope component developed two different approaches for implementation and effectiveness monitoring, a semi-quantitative/categorical "random transect approach" (roughly modeled on the procedures used by the U.S. Department of Agriculture, Forest Service) and a more subjective "whole THP approach." Time and resources allowed only the first to be tested during the PMP. Of the roughly 1300 Rule provisions related to water quality protection, only 154 can be categorically monitored in the field following a timber operation. The random transect approach provides a detailed evaluation of observed problems, quality of implementation, and degree of effectiveness (on the hillside, not in a watercourse or lake) for each of these 154 Rules. It appears that this approach can be effectively carried out by trained personnel who are familiar with the Rules and the Process. It also appears that the training program was effective in preparing CDF Forest Practice Inspectors to carry out the approach. The random transect approach samples only a small portion of each timber operation, and, on a given timber operation, it is likely to miss the relatively rare, but critical, areas that produce most of the sediment impacts on water quality. The whole THP approach provides a way to evaluate these critical sites and to evaluate compliance with 92 Rule intent statements and/or performance standards that are too subjective to evaluate quantitatively.

The hillslope component data management system was not fully developed until July 1996. Currently, the database and the data collected during the PMP are being evaluated to determine the best statistical procedures for analyzing data collected during the LTMP.

Approaches for evaluating the effectiveness of nonstandard practices and the Process were only started during the Pilot Program and further work is needed in both of these areas. Delivery of sediment through Class III watercourses would probably need to be evaluated by a research effort too rigorous to be carried out on a statewide scale.

The major PMP products include the following items:

- A final report prepared by Stephen Rae, DFG Project Manager, dated December 20, 1995, and entitled, "Board of Forestry Pilot Monitoring Program: Instream Component."
- An instream monitoring training curriculum (which largely evolved into the curriculum for the initial Watershed Academy at Humboldt State University, August and September 1995).
- A functioning database established in DFG for storing, analyzing, and reporting PMP and LTMP instream monitoring data.
- A final report prepared by Dr. Andrea Tuttle, CDF consultant, dated March 1, 1995, entitled, "Board of Forestry Pilot Monitoring Program; Hillslope Component," and including a set of field forms and instructions for use.
- A database established by CDF for storing, analyzing, and reporting PMP and LTMP hillslope monitoring data.
- A final report prepared by Thomas Spittler, DMG Project Manager, dated 1995, and entitled, "Pilot Monitoring Program: Geologic Input for the Hillslope Component," including maps for three selected watersheds.
- A final report by Dr. Don Erman, Nancy Erman, and Ian Chan, CDF consultants, dated January 22, 1996 and entitled, "Pilot Monitoring Program: Review and Final Recommendations Prepared for the Monitoring Study Group."

The PMP showed that State agencies and landowners can work together effectively and successfully in conducting monitoring activities.

Due to the difficulty in finding suitable spatial and/or temporal controls, it is highly unlikely that project monitoring can be meaningfully carried out using a quantitative approach at randomly selected timber operations scattered across the State.

The LTMP should be integrated and consistent with requirements emerging from currently ongoing governmental and legal activities. As those requirements become clear, MSG should reconsider the LTMP, its objectives and approaches, and recommend changes. The February, 1995 BOF commitments should be aggressively pursued.

MSG's current recommendations for the LTMP include the following:

- The instream monitoring approaches and protocols being used in forested watersheds by the private sector and USFS should be periodically reviewed and evaluated.
- At least one cooperative monitoring watershed where landowners and agencies will coordinate and integrate instream and hillslope monitoring and share data should be established on a pilot basis and establishment of other cooperative monitoring watersheds should be encouraged.
- Instream trend monitoring should be encouraged in cooperative monitoring watersheds to determine long-term changes in watershed/instream conditions.
- The capability of the DFG database to handle instream monitoring data should be verified.
- The PMP random transect procedure should be carried out by private RPFs (other than CDF foresters) at randomly selected timber operations with CDF providing training, reference materials, oversight, and QC auditing.
- CDF should further develop its hillslope monitoring database and complete the ongoing study evaluating the utility and value of various statistical approaches (including nonparametric statistics) for analyzing hillslope monitoring data.
- The hillslope monitoring procedures developed but not yet tested during the PMP should be tested and refined.

ACKNOWLEDGMENTS

Pete Cafferata and John Munn made enormous contributions to the Pilot Monitoring Program (PMP). They managed California Department of Forestry and Fire Protection (CDF) contracts, helped the Monitoring Study Group in a variety of ways, developed and tested field forms for the hillslope component, and coordinated development of the CDF PMP data management system.

Elmer Dudik and Chris Knopp, Regional Water Quality Control Board staff, provided invaluable technical expertise and field savvy for the instream component.

Staff of Georgia-Pacific Corporation, Gualala Redwoods, Inc., and Fruit Growers Supply Company generously provided maps of and keys to company lands, personal knowledge and insight regarding past land management and current access, stream and timber operation conditions. They were ready and willing to guide and help in a variety of field functions.

These acknowledgments would not be complete without a special recognition of Gil Murray, then President of the California Forestry Association. Before his death, his efforts and ability to help others see the need for monitoring and its potential value was instrumental in obtaining their cooperation during the PMP.

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LIST OF ABBREVIATIONS

BMPs -- Best management practices (see Glossary)

BOF -- State Board of Forestry

CDF -- California Department of Forestry and Fire Protection

DFG -- California Department of Fish and Game

DMG -- California Department of Conservation, Division of Mines and Geology

FPRAT -- Forest Practice Rules Assessment Team

FRAP -- Fire and Resource Assessment Program

LTMP -- Long Term Monitoring Program

LTO -- Licensed Timber Operator

MAA -- Management Agency Agreement executed between the SWRCB, BOF, and CDF

MSG -- Monitoring Study Group

PMP -- Pilot Monitoring Program

QA -- quality assurance (See Glossary)

QC -- quality control (See Glossary)

RPF -- Registered Professional Forester

Rules -- Forest Practice Rules

Rules/BMPs -- Those Rules certified by the SWRCB as BMPs

RWQCB -- California Regional Water Quality Control Board

SWRCB -- State Water Resources Control Board

THP -- Timber Harvesting Plan

USEPA -- U.S. Environmental Protection Agency, Region 9

USFS -- U.S. Department of Agriculture, Forest Service, Region 5

CHAPTER I.--INTRODUCTION

Purpose of This Report

This report is intended to do the following:

1. Help the general reader in comprehending the complex subject of monitoring so that the remainder of the document is more readily understandable.

2. Summarize and integrate the results of the Board of Forestry (BOF) Pilot Monitoring Program (PMP) and the important lessons learned from it.

3. Set forth and evaluate the options for a BOF Long Term Monitoring Program (LTMP).

4. Provide a set of recommendations for the LTMP that are intended to:

    a. Provide program objectives that are worth pursuing and achievable, and

    b. Establish a program that will be feasible, efficient, and effective in achieving those objectives.

Organization of This Report

The first two chapters summarize the historical and conceptual background for the PMP. They can help the general reader understand the reasons for (and the significance of) what follows, including the many decisions regarding the PMP, the lessons learned from the PMP, the options for an LTMP, and the current Monitoring Study Group (MSG) recommendations for an LTMP. Chapter III provides a summary overview of the PMP. Chapters IV, V, VI, and IV summarize the objectives, procedures, and results of the PMP site selection process, the PMP instream component, the PMP hillslope component, and the PMP geologic element, respectively. Chapter VIII synthesizes the important lessons and conclusions drawn from the PMP and its components. Chapter IX presents major issues facing the LTMP, options for addressing them, and alternative LTMP funding scenarios. Chapter X sets forth MSG's current recommendations for an LTMP.

The report contains many abbreviations, acronyms, and technical terms. The word or phrase associated with each abbreviation and acronym is shown in the List of Abbreviations. Many technical terms are explained or described in the glossary. Glossary terms are set in **boldface** where they first occur in the body of the report.

Full reports on the instream (Rae, 1995) and hillslope (Tuttle, 1995) components and the geologic element (Spittler, 1995) are not included in this report but are available upon request to CDF in Sacramento. Similarly, the scientific review report for the PMP (Erman, *et al.*, 1996) is available from CDF. The Appendix includes a brief summary of the California Department of Forestry and Fire Protection (CDF) monitoring contracts that are related to the PMP.

Historical and Legal Background

The State's Z'Berg-Nejedly Forest Practice Act of 1973 and the Forest Practice Rules (Rules) promulgated by BOF apply to all timber operations on nonfederal lands in the State. The Rules are administered by CDF. The Rules prescribe a wide variety of forest practices related to water quality, including practices for silvicultural methods, harvesting, yarding, landings, logging roads, erosion control, site preparation, watercourse and lake protection, and fire hazard. In addition to the **standard practices** prescribed by the Rules, they allow use of **nonstandard practices**. Nonstandard practices provide the flexibility needed to deal with the great variability in California's timberlands. The **Process** by which the Rules are implemented and administered includes two major components: (a) Timber Harvesting Plan (THP) preparation by a Registered Professional Forester (RPF), review by an interagency Review Team including representatives from an appropriate California Regional Water Quality Control Board (RWQCB), and approval by CDF, and (b) conduct of a timber operation by a licensed timber operator (LTO) with inspections by CDF inspectors. BOF and CDF have often stressed that the Process is as important as the Rules in achieving protection of the quality and **beneficial uses** of the State's waters.

In 1977, BOF, CDF and the State Water Resources Control Board (SWRCB) began a process to review the adequacy of the Rules as **best management practices (BMPs)** pursuant to Section 208 of the Federal Clean Water Act. In 1983, after extensive review and revision of the Rules by BOF, the SWRCB temporarily certified them as BMPs on the condition that: (a) a four-year monitoring and assessment program be established, and (b) a Management Agency Agreement (MAA) be executed between BOF, CDF, and the SWRCB. The anticipated monitoring and assessment program turned out to be too costly to implement, and the MAA was not finalized.

To break this impasse, the agencies agreed to conduct a one-year **qualitative** assessment using a small multidisciplinary Forest Practice Rules Assessment Team (FPRAT). FPRAT was formed in 1985 and visited 100 timber operations scattered around the State during 1986. The team's report (FPRAT, 1987) stated that:

1. With certain important exceptions, the standard practices set forth in the Rules appeared to provide adequate protection of the quality and beneficial uses of water where appropriately implemented.

2. Use of nonstandard practices frequently resulted in less protection than would have been provided by the standard practices.

3. Poor Rule implementation was the most common cause of observed water quality impacts associated with timber operations.

4. The persons responsible for preparing, reviewing and approving a THP frequently never saw the actual effects of the timber operation. Therefore, the insight that they might have gained from this experience could not be used to guide their decisions regarding new THPs.

5. This kind of feedback loop should be explicitly integrated into the Process.

In 1988, following extensive public review and pursuant to Section 208, the SWRCB: (a) certified a Water Quality Management Plan for Timber Operations on Nonfederal Lands, including the Process, certain Rules (which were certified as the plan's BMPs), and an MAA, (b) executed a MAA with BOF and CDF, and

(c) designated BOF and CDF as joint management agencies for implementing the plan. Among other things, the MAA identified many issues for further resolution through regulatory and/or nonregulatory means, and it provided that those Rules certified as BMPs (**Rules/BMPs**) and the Process would be reassessed after the issue resolutions had a chance to become established.

Accordingly, BOF formed MSG to explore and, if possible, develop an ongoing monitoring program. The MSG includes representatives from the California Licensed Forester's Association, California Forestry Association, the environmental community, SWRCB and California Regional Water Quality Control Board, North Coast Region (RWQCB), California Department of Fish and Game (DFG), California Department of Conservation, Division of Mines and Geology (DMG), CDF, U.S. Department of Agriculture, Forest Service (USFS), U.S. Environmental Protection Agency (USEPA), and a BOF member who acts as chairperson.

In 1991, CDF obtained funding ($250,000/year) to conduct monitoring, and the SWRCB approved BOF-proposed workplans to use $149,000 of USEPA Clean Water Act Section 319 grant monies to help fund MSG efforts.

At the recommendation of MSG, BOF appointed a BMP Effectiveness Assessment Committee (BEAC). The BEAC was designed to give the public early input into development of the monitoring program and to discover which forest practices and watersheds the public felt had the greatest priority for monitoring. The BEAC, with the assistance of a contractor paid from the Section 319 monies, held workshops throughout the timber-producing regions of the State. The BEAC submitted its report (BEAC, 1991) to MSG late in 1991. BEAC (1991) stressed the importance of the monitoring program and its results being acceptable and believable by a majority of the interested parties.

Based on BEAC (1991) and on its own knowledge regarding technical, institutional, and financial constraints, MSG prepared a report (MSG, 1993) with the continuing assistance of the contractor. MSG (1993) recommended that:

1. The primary goal of an LTMP should be to provide an ongoing assessment of the effectiveness of the Rules, as implemented, in protecting the most sensitive beneficial uses of water (i.e., cold water fisheries and domestic water supplies) through implementation monitoring, effectiveness monitoring, and project monitoring.

2. The LTMP results should be provided to BOF and the public in a timely manner to contribute effectively to BOF's program for reviewing and, where necessary, strengthening the Rules' performance as BMPs.

3. A PMP should be completed before implementation of a full scale LTMP.

Accordingly, the PMP was conducted primarily between June 1993, and December 1994. More detail is provided in following chapters.

Early in 1995, two reports were submitted to BOF (CDF (1995) and Greenwood and Smith (1995)). Both reports identified the continuing controversy over the effectiveness of nonstandard practices, and they stressed the need for a reliable monitoring program to help resolve this and other continuing issues. Also, MSG asked BOF for support in several areas. As a result, BOF voted unanimously to:

1. Treat the LTMP as one of its highest priorities and make a strong commitment to its continuation, including iterative refinements of techniques for field monitoring and data management and additions to them.

2. Seek an appropriate level of secure funding for CDF to allow the LTMP to be an ongoing program.

3. Promote CDF priorities that will allow adequate staff time for continued development and implementation of hillslope monitoring while appropriate outreach training programs are being established.

4. Support other agency efforts to establish outreach training programs for instream monitoring (i.e., the Watershed Academy).

5. Encourage private landowners and the public to cooperate in the LTMP, particularly through self-monitoring and project monitoring.

6. Solicit and encourage the high-level involvement and cooperation of other State agencies in the LTMP, encourage them to make it one of their highest priorities, and work with them to obtain adequate funding and resources.

Control of Nonpoint Source Pollution

A **nonpoint source** of pollution typically comprises a widely distributed land management activity (e.g., silviculture, mining, agriculture, grazing) generating pollution that has no readily apparent point of discharge and/or that cannot feasibly be controlled by collection and treatment once it has been generated. Therefore, the goal of nonpoint source pollution control is to prevent or reduce the generation of nonpoint source pollution, usually through application of BMPs certified by the SWRCB under the authority and resources of a management agency designated by the SWRCB. This BMP/management agency approach is intended to protect beneficial uses of water and achieve compliance with applicable water quality requirements.

When approved or adopted by the SWRCB, the following types of water quality requirements may apply to a timber operation:

1. Discharge prohibitions set forth in a Water Quality Control Plan.

2. Water quality standards set forth in a Water Quality Control Plan. Such standards typically comprise the designated beneficial uses of a stream, lake, estuary, bay, wetland, or aquifer, together with the narrative or numeric water quality objectives deemed necessary to protect and maintain those uses. Water quality means the chemical, physical, biological, bacteriological, radiological, and other properties and characteristics of water which affect its use.

3. State and Federal policy regarding protection of high-quality waters.

Pursuant to the Federal Clean Water Act, the BMP/management agency approach is intended to be iterative. The performance of BMPs, the BMP implementation procedures, and the management agencies must be reviewed as part of a continuous SWRCB planning process. Improvements must be made when warranted by: (a) changes in technical, environmental, economic, and/or institutional constraints, (b) changes in legal requirements for water quality protection, and/or (c) new evidence provided by monitoring. This is one major reason the MAA provided for reassessment of the effectiveness of the Process and Rules/BMPs.

CHAPTER II.--CONCEPTUAL BACKGROUND

Major Types of Monitoring

As MSG uses the term, monitoring means repeated observations or measurements performed over space and time: (a) for the purpose of detecting change over time in some factor of interest, and (b) in situations that are not created largely or entirely for such observation or measurement. Monitoring is distinguished from inventory and assessment by the intent to detect change over time. Research is distinguished from monitoring by the use of experimental situations that are planned and designed from the beginning to obtain data for proving or disproving a hypothesis and that have adequate **controls**. The major kinds of monitoring are summarized below and some of their characteristics are summarized in Table 1.

Hillslope Monitoring and Instream Monitoring

Implementation monitoring and effectiveness monitoring are typically carried out on the hillslope and do not include measurement or observation of instream condition. The other kinds of monitoring are typically carried out in a body of water. In this report, implementation and effectiveness monitoring are collectively termed hillslope monitoring, and the other types are collectively termed instream monitoring (Table 1).

Implementation Monitoring

This variety of monitoring would be used to determine the degree to which, during timber operations, Rules/BMPs and/or THP-specific nonstandard practices have been carried out. It would also be used to determine the degree to which the Process (including THP preparation, review, and approval) has been carried out as required or intended. Typically, implementation monitoring does not involve field measurements and does not require repeated site visits for a given issue. The uses and benefits of implementation monitoring are as follows:

1. It addresses the Process, a major source of water quality impacts documented by FPRAT (1987).

2. It establishes a necessary base for effectiveness monitoring, because the effectiveness of a Rule/BMP cannot be reasonably determined where it has not been appropriately implemented.

3. It provides immediate feedback to BOF decision makers and/or CDF managers on how well the Rules/ BMPs and the various elements of the Process are being implemented as a whole and individually.

4. It can help to determine the importance and necessity of the Process and its various elements in achieving effective Rule/BMP implementation.

5. It can help to determine what refinements in the Process and its elements would be appropriate.

Effectiveness Monitoring

Effectiveness monitoring would be used to determine the degree to which any Rule/BMP (or any nonstandard practice specified in a THP) is effective in accomplishing its immediate objectives on the hillside (e.g., to prevent or reduce generation of discharges from a road). Effectiveness evaluations are usually made at or very near the site of a practice and are rarely made in a stream channel or riparian area. To address the issues of landsliding and severe storm events, effectiveness monitoring may need to be conducted repeatedly and/or over several years for a given timber operation. It is particularly appropriate for addressing nonpoint source pollution. The uses and benefits of effectiveness monitoring include the following:

1. The results are necessary to relate what happens on a hillslope and what happens in a stream.

2. It provides immediate feedback to BOF decision makers and/or CDF managers on how effective, as implemented, the Rules/BMPs are in meeting their immediate objectives.

3. It can help to determine the relative importance, necessity, and effectiveness of various Rules/BMPs.

4. It can help to determine what refinements in the Rules/BMPs would be appropriate.

Where project monitoring is not feasible or where variability in stream **monitoring parameters** is too high, effectiveness monitoring will usually provide the closest feasible surrogate measure of the possible impacts of project activities on beneficial uses of water.

Project Monitoring

Project monitoring evaluates the degree to which: (a) the condition of a **project stream reach** changes over time, and (b) any detected changes may be associated with a specific project (e.g., a timber operation). Project monitoring addresses a project as a whole, rather than individual practices. Project monitoring must be closely coordinated and integrated with effectiveness monitoring. It typically requires use of temporal controls and/or spatial controls to distinguish changes due to a project from those due to other environmental and management variables. Due to the lag time between land use activities and the occurrence of a stressing climatic event, project monitoring may often need to be continued for a long time to detect any instream effects.

A full-scale, rigorous, limited, and expensive research design would be needed to document the degree to which a timber operation or a particular forest practice has caused a change in stream sediment conditions. The Caspar Creek Watershed Study on Jackson Demonstration State Forest is an example of this type of monitoring (Ziemer, *et al.*, 1996). An approach this rigorous is neither effective nor efficient for a statewide program. Results from less rigorous project monitoring of many timber operations for a long period may allow development of a **statistical association** between certain sets of practices on the hillslope, certain environmental conditions, and certain changes in stream condition. Such results may be helpful in determining:

1. The significance and types of instream changes that show a strong statistical association with: (a) timber operations (as a whole), certain sets of Rules/BMPs, and/or certain kinds of nonstandard practices and/or (b) certain environmental and instream characteristics.

2. The relative importance, effectiveness, and necessity of various sets of Rules/BMPs in protecting beneficial uses.

3. The Rules/BMPs and/or nonstandard practices for which refinements would be appropriate.

Project monitoring is the only way to rigorously document the effectiveness of the Rules/BMPs, as implemented, in protecting the quality and beneficial uses of water. Many instream monitoring approaches may be used for both project monitoring and trend monitoring.

Trend Monitoring

This kind of monitoring would be used to detect the degree of long-term change in the condition of a **stream reach**, lake or watershed. Trend monitoring should be done at the key points where the probability of detecting such changes is high; usually this would *not* be associated with any particular timber operation. A trend monitoring program needs to be based on the results of a reliable watershed assessment and tailored appropriately for the issues affecting a particular watershed or water body (Rae, 1995). Trend monitoring results can be difficult to interpret due to the multitude of environmental and management influences, lag times, and recovery times in a watershed. Nevertheless, trend monitoring may be used to evaluate:

1. Changes in stream channel conditions through time.
2. In combination with implementation and effectiveness monitoring, the degree to which management activities in a watershed may be contributing to cumulative watershed effects.

Trend monitoring is appropriate for watersheds where there are important issues, including those basins: (1) that are designated as sensitive by BOF, (2) that are listed as threatened or impaired pursuant to the Federal Clean Water Act, (3) that provide habitat for a species designated as sensitive by BOF or as threatened or endangered pursuant to State or federal Endangered Species Acts, or (4) where there is considerable debate or litigation regarding the effects of certain activities.

Compliance Monitoring

This type of monitoring addresses the degree to which one or more applicable water quality requirements are being violated. Existing State and federal water quality standards use water column parameters that were developed primarily to deal with point source pollution. They often do not adequately represent: (a) the kinds of pollutants from timber operations, (b) the kinds of changes in the physical and biological attributes of channels, beds, and banks that these pollutants may cause, or (c) the associated changes in affected beneficial uses. Compliance monitoring would not be highly relevant to the LTMP absent more relevant standards. Also, it is the role of SWRCB and RWQCBs, not BOF, to promulgate water quality standards or water quality models and determine compliance with them.

Validation Monitoring

Validation monitoring is used to test the accuracy and reliability of a model or hypothesis. To varying degrees, all monitoring is validation monitoring. Appropriate specification of the hypothesis being tested can help to refine a monitoring program.

Baseline Monitoring/Assessment

This kind of assessment is intended to help characterize existing instream or watershed conditions and/or to establish a background for planning or future comparisons. It might provide a temporal control, although it is usually not conducted for a long enough time and over a wide enough range of climatic events for this benefit to be fully realized.

Levels of Monitoring, Information Quality, and Certainty

Monitoring can be carried out to provide several different levels of information quality with corresponding degrees of certainty and confidence in the information. Table 2 provides a matrix for four levels of monitoring. The lowest level of monitoring relies heavily on experience and professional judgment and provides subjective qualitative determinations of obviously "good" or "bad" conditions. It is most appropriate for situations where a fairly high risk of error in decision-making is acceptable. The next step up often relies largely on "calibrated eyeball" approaches and/or on **semi-quantitative/categorical** ranking of observations by experienced professionals. It is most appropriate for situations where a moderate risk of error is acceptable. A third level relies to a major degree on **quantitative** monitoring, and it is most appropriate for situations where only a low risk of error is acceptable. The highest level is characteristic of research. It is most appropriate where only a very small risk of error is acceptable (e.g., where scientific or legal "proof" is needed).

Usually, the monitoring level selected represents a tradeoff between what is ideal and what is feasible. The level of monitoring strongly influences and is influenced by the available resources, time, expertise, and by the cost and stringency of the monitoring approaches. An effective monitoring project will collect information that meets or exceeds the quality and confidence needed to address the objectives; an efficient monitoring program will avoid expenditures for a higher level of quality and confidence than is actually needed. A monitoring program may include several different levels of monitoring.

The quality of information needed to support a decision also depends on the degree of polarization and controversy surrounding an issue. In highly polarized situations, each side typically demands that the other support its position with very high quality information. Where the sides have agreed on the utility and desirability of a specific detailed monitoring program, and have developed a sense of ownership, commitment, and confidence toward the program, they will often jointly accept a lower level of information quality. BOF and MSG recognized the importance of this widespread trust and involvement from the beginning of this effort, and it was a reason that they established the BEAC to help in program formulation.

Statistical Design

Appropriate statistical design is critical for drawing sound statistical conclusions from quantitative monitoring data. It needs to be incorporated into initial program planning as it will guide the sampling, number of sites to sample, the statistical analyses to be used, and confidence in the results. Appropriate statistical design may have the following benefits:

1. Help determine how many samples are likely to be needed to: (a) characterize a parameter with a specified degree of uncertainty, and (b) determine if there is a significant difference between locations or change over time.

2. Reducing costs by optimizing the times and locations for sampling.

3. Guide the selection of the parameters to be measured.

4. Help determine the needed **precision** and **accuracy** of the data.

5. Provide analytical testing procedures to ensure the strongest, most reliable results and conclusions.

Quality Assurance/Quality Control

Quality assurance (QA) and **quality control** (QC) are critical for ensuring the accuracy and reliability of monitoring results and confidence in the information, especially for higher, more quantitative levels of monitoring. Usually, they should be incorporated into initial program planning. A QA/QC program will vary by monitoring level and the variable(s) being monitored. Usually, the QA component will include the following: (a) detailed objectives, (b) reference materials, (c) a training program, and (d) minimum personnel qualifications. The QC component comprises procedures to detect and correct errors and omissions. The following discussion of some basic ingredients of a QA/QC program is derived from Dissmeyer (1994).

Detailed Program Description

A monitoring program description should explicitly describe specific program goals and objectives. Many monitoring programs have learned the hard way how vital this is to an effective and efficient program. A monitoring program description should also describe the following: (a) how the parameters to be used and the data to be collected are expected to meet the program goals and objectives, (b) program organization (i.e., how the project will be conducted), (c) organizational responsibilities and functions, and (d) the key individuals responsible for collecting and handling data and for ensuring precision and accuracy of data analyses, including their minimum qualifications, level of expertise, and their responsibilities (especially when an activity relies on professional judgment).

Reference Materials

Written reference materials should specify quantitative objectives for each quantitative parameter to be monitored, including objectives for precision, accuracy, **repeatability, completeness**, **representativeness**, and **comparability**.

Field sampling **protocols** should be fully specified for each monitoring parameter, including all of the steps to be taken to ensure the quality of samples and sample data. Such protocols may include the following: (a) specific physical, chemical, biological, and habitat variables to sample; (b) the target assemblages of species for biological variables; (c) sampling methodology; (d) habitat-assessment methodology; (e) details of sample preservation; (f) use and calibration of instruments; (g) replication and other QC requirements; (h) sampling site selection; and (i) methods of taking and recording field measurements.

Where laboratory analysis is needed, the laboratory protocols should be specified for: (a) the methods of sample and data analysis to be used (including appropriate literature references), and/or (b) detailed operating procedures, including sample preparation and analytical procedures.

Data management protocols should be specified to ensure that data quality is maintained throughout data reduction, validation, transfer, storage, retrieval, and reporting. For example, biotic samples should be checked for proper taxonomic identification and forms checked for completeness, recording errors, plausibility, and consistency.

A specific program of routine inspection, calibration, and preventive maintenance should be established to ensure that field and laboratory equipment is functioning at an optimal level and that data quality remains consistently high.

A specific chain-of-custody procedure should be established to ensure a written record traces the possession of each sample and/or field data set from the time of collection through data analysis.

Copies of the relevant reference materials should always be readily available to all participants. Employing standardized and consistent data forms and survey protocols maximizes comparability.

Training

All personnel participating in monitoring activities should be trained and provided with adequate experience in applying the protocols and in the proper use, maintenance, and limitations of each piece of equipment for sampling, measuring, or analyzing. Such training and experience are the most effective way to ensure the precision, accuracy, consistency, and repeatability of data and results.

QC Program

An effective QC program can detect errors and omissions at any point in the project implementation process. The program should be able to identify problems and their source, implement action to correct them, document results of corrective action, and continue the process until each problem is eliminated. QC checks on the procedures used by field personnel should be done periodically during the field season. Internal QC checks can include replicate samples at stations to check consistency of collection, repeat field collections by separate crews, etc. If any problems are found, corrective action should be taken immediately.

Developing a Monitoring Program

The conceptual framework provided by MacDonald, *et al.* (1991) for development of a monitoring program underlies this report as a whole as well as the discussions set forth in many chapters (Figure 1). An established monitoring program is often considered as a final, fixed design, and it takes on a life of its own. In such a situation, there is little incentive to analyze the data as it is collected, and modifying the program is difficult, although it may not be meeting the original objectives. Early assumptions and decisions incorporated into a monitoring program often contain unrecognized mistakes. As more is learned and the initial mistakes become evident, a program may need to be substantially changed (or abandoned), and the information collected during the first few years may have to be discarded because it is irrelevant, unreliable, or inconsistent with later information. To avoid this, several authors have recommended that development of a long term monitoring program include an explicitly recognized pilot phase (See Figure 1). A pilot phase is far easier to modify because it is conducted on a trial basis. It provides a test of the program's objectives and of the feasibility and utility of proposed monitoring approaches. The results of a pilot phase can lead either to a revision of the monitoring program or to continued monitoring. Usually, a properly formulated pilot phase will result in some modifications to the monitoring procedures, but will not alter the basic structure or objectives of the overall monitoring program.

As presented by MacDonald, *et al.* (1991), the benefits of a pilot phase can include the following:

1. Early identification and correction of unanticipated problems and mistakes.

2. Helping to ensure that the program objectives are reasonable and achievable.

3. Helping to ensure that the program design, monitoring parameters and protocols, QA/QC program, and data management system are feasible, useful, effective and efficient.

4. Providing much of the initial data set needed for: (a) testing the proposed program design to help ensure that it is efficient in terms of its overall structure and sampling procedure and that it can generate data that will support program objectives, and (b) testing the structure and functionality of the data management system.

5. Allowing time for personnel to become familiar with sampling devices and analytical equipment, thus improving the reliability of subsequent data.

6. Allowing responsible parties to go through each stage of developing and implementing a monitoring plan, but without a long term commitment of resources.

7. Allowing the methodology to be adapted to the conditions and variability found in the field.

8. Providing an impetus for the rapid analysis of field data, and subsequent modification of the monitoring plan.

9. Enhancing the potential for communication among all those involved in the monitoring project--technicians, statisticians, managers, and technical specialists.

10. Helping to avoid changes in parameters or protocols that could preclude any statistical comparisons with earlier data.

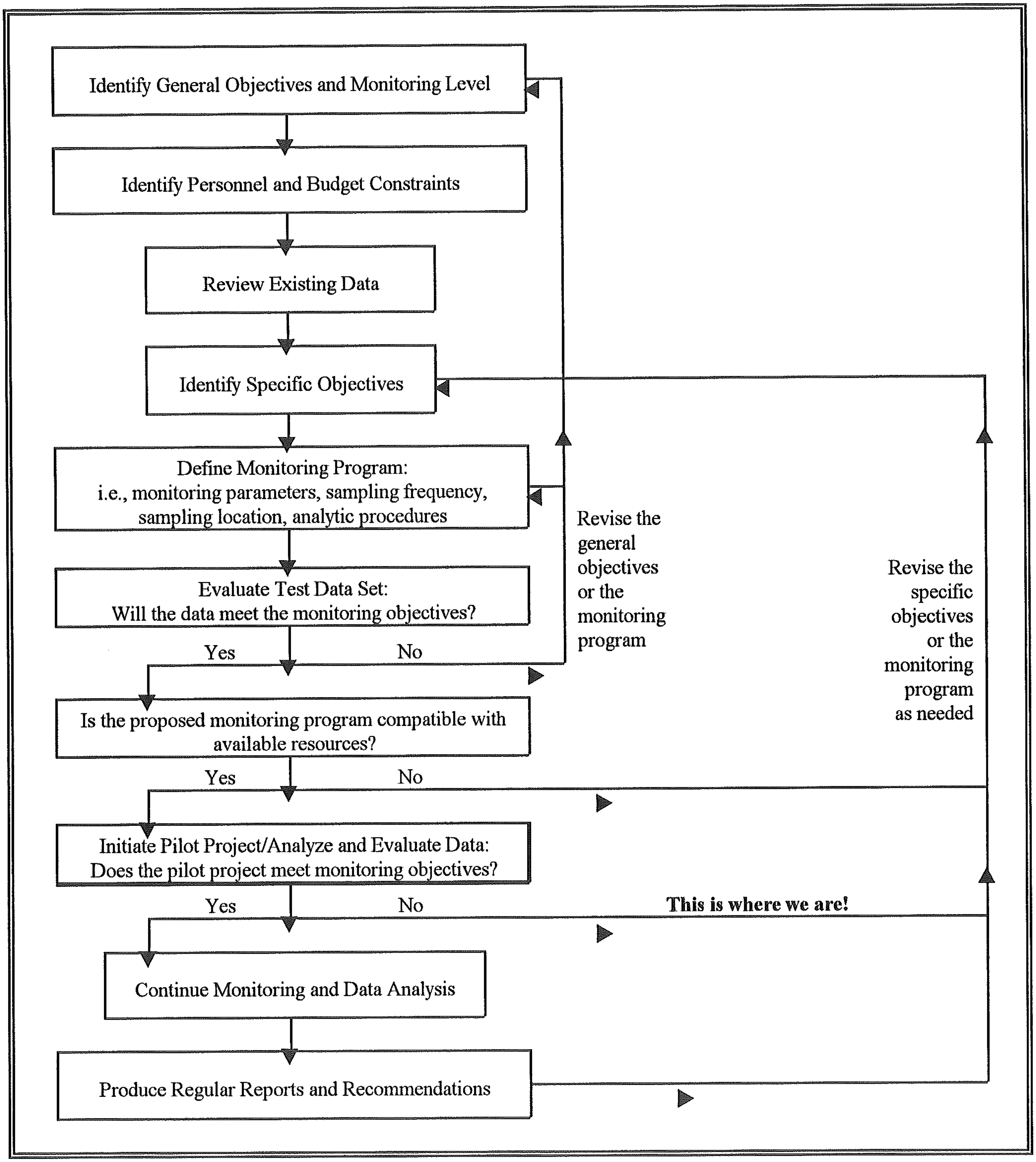
Table 1.--Some Characteristics of Various Types of Monitoring (After MacDonald, *et al.*, 1991)

Type of Monitoring		Number and Type of Parameters	Relative Frequency of Measure-ments	Relative Duration of Monitoring	Relative Intensity of Data Analysis	Addresses the Degree to which and (Sometimes) under What Conditions:
Instream	Baseline	Many instream parameters, including water column parameters; hydrologic, geomorphic, biologic parameters: bed and bank parameters; habitat conditions	Low	Medium to short, preceding trend or project monitoring	Low to moderate	Background stream conditions/ instream parameters are variable
	Trend	Same as above	Low	Long	Low to moderate	Long-term changes are occurring in stream conditions/ parameters
	Project	Variable instream parameters, usually few for any given project	Medium to high	Varies; usually exceeds project duration	Medium to high	A "project" or activity is associated with instream changes
	Validation	Few instream parameters and sometimes hillslope parameters	High	Usually long to medium	High	A model or hypothesis accurately represents observed conditions
	Compliance	Few instream parameters	Variable	Dependent on project	Moderate to high	A project achieves compliance with applicable water quality standards
Hillslope	Implementation	Few to many parameters; no water quality parameters	Variable	Short, during and following project	Low to moderate	Specified/required practices have been carried out during a project
	Effectiveness	Few to many hillslope parameters; few or no water quality parameters	Medium to high	Medium to short, during and following project	Moderate	Specified/required practices have prevented or reduced the generation of discharges

Table 2.--Some Characteristics of Four Monitoring Levels (after Dissmeyer, 1994)

Monitoring Level	Quantity and Type of Information Produced	Quality of Information Produced	Levels of Uncertainty and Risk	Typical Uses of Information	Skill Levels Needed for Instream	Control and Study Streams Used	Time to Decision
I	Small to moderate amount of information, mostly empirical observations by experienced professionals; subjective rating of obviously "good" or "bad" conditions; little or no quantitative data	Large intermediate gray area where significant impacts and/or changes are likely to be missed; very imprecise; may be inaccurate	High uncertainty; high risk of making erroneous decisions	Early warning system; obvious Y/N screen for implementation and effectiveness; project complaint; management decisions by individual landowners	One or two trained professionals with a technician	One study stream; upstream/ downstream controls; state ecoregion reference stream	Few hours to a few days
II	Moderate to large amount of information; largely qualitative and/or semi-quantitative data; little quantitative data	Gray area is moderate; somewhat more objective, but still largely subjective; much more accurate; moderately precise	Moderate uncertainty; reduced risk of a wrong decision	Complaint involving high-value/public interest stream; implementation, effectiveness, and validation monitoring; revision of voluntary BMPs; cooperative land management decisions	Two trained professionals (hydrology, fisheries, habitat, invertebrates); technicians	2-3 study streams plus controls; plus info on stream order, channel class, riparian and slope vegetation	15-30 days
III	Large to very large amount of information; primarily quantitative data with limited semiquantitative or qualitative data	Gray area is small; most significant impacts and/or changes are detected; much more objective; much improved precision and accuracy	Low uncertainty; allows well-informed, objective defensible decisions with a low risk of error	Same as level II, plus compliance monitoring; revision of mandatory BMPs and regulations; establishing statistical cause/effect association and/or desired future condition	Several professionals in above disciplines plus statistics and channel geomorphology; several technicians	3 or more study and control reaches depending on statistical design; use of detailed stream/ ecoregion stratification	2-3 months for initial visits to reaches; 2-3 years for repeated visits for some issues
IV	Very large amount of narrowly focused information; almost exclusively quantitative data	Gray area is very small; small changes or impacts are detectable; highly objective; very precise and accurate	Very low uncertainty; allows highly objective, defensible, data-based decisions with very low risk of error.	Scientific and legal proof of cause and effect; litigation; revision of mandatory BMPs and statutes	Same as above, but often including researchers	Same as above	2 years or more

Figure 1. Development of a Monitoring Program (after MacDonald, *et al*, 1991)



CHAPTER III.--SUMMARY DESCRIPTION OF THE PMP

Goals of the PMP

MSG (1993) recommended that the PMP be initiated to provide a practical, small-scale, short-duration test of several critical aspects of the LTMP. Beyond realizing the benefits mentioned at the end of the preceding chapter, the goals of the PMP included the following:

1. To help ensure that the quality of LTMP monitoring data would be high enough to support program objectives by: (a) developing and implementing training programs and field reference material, forms, and instructions for field monitoring crews, and (b) reviewing the feasibility and effectiveness of the training and materials.

2. To help ensure that monitoring data would be reproducible, repeatable, reliable, and consistent by: (a) selecting, developing and implementing a "toolbox" of proposed approaches for monitoring and QA/QC , and (b) reviewing their feasibility, effectiveness, and utility.

3. To help ensure that monitoring data could be managed consistent with LTMP objectives by: (a) developing and implementing proposed **data management systems,** and (b) reviewing their feasibility, effectiveness, and utility.

4. To help ensure that the approaches being considered and tested can provide meaningful results, are cost-effective, and are not likely to be changed later.

5. To give managers reliable information regarding the funding, time commitments, and resources needed to establish and maintain an LTMP.

6. To determine the reasonableness of the proposed LTMP objectives and the feasibility of achieving them.

Items Beyond the Scope of the PMP

Because of its limited scope and duration, the following items were beyond the scope of the PMP:

1. The status of or changes in watershed conditions or cumulative watershed effects.

2. The status of or changes in stream reach conditions or instream effects of a timber operation.

3. The implementation or effectiveness of any Rules/BMPs or any part of the Process.

4. Compliance with water quality requirements.

Objectives of the PMP

The PMP's objectives were as follows:

1. To select enough suitable sites (about 30) to allow statistically meaningful testing and analysis.

2. To select the instream monitoring parameters and protocols and develop the hillslope monitoring techniques and protocols to be used and tested.

3. To select and/or develop the related reference materials, forms, instructions, and QC programs to be used and tested.

4. To prepare training programs for the field personnel who would be using and testing the instream and hillslope parameters, techniques, etc. in the field.

5. To select appropriate field personnel.

6. To train these personnel in: (a) the monitoring parameters, techniques, protocols, field reference materials, forms, and QA/QC protocols, and (b) use of the field equipment, including hands-on experience.

7. To conduct field testing of instream and hillslope monitoring approaches using trained personnel.

8. To conduct geologic and geomorphic mapping to establish the environmental context for both instream and hillslope testing.

9. To develop appropriate data management systems based on the field data forms.

10. To revise the training programs and the field reference materials, forms, and instructions as needed to improve their clarity, utility, effectiveness, and efficiency, based on the experience gained during the training exercises, early field work, and data management system development.

11. To test the data management systems using the field data.

12. For both the instream and hillslope components, to review the necessity, feasibility, utility, functionality, cost, effectiveness, and efficiency of: (a) the training materials and program; (b) the personnel qualifications; (c) the site selection approach; (d) the monitoring parameters, techniques, and protocols; (e) the reference materials and QC programs; (f) the geologic/geomorphic mapping; and (g) the data management systems.

MSG (1993) contained several recommendations for the PMP related to: (a) who should do the testing, (b) what parameters should be tested, and (c) where, when, and how testing should take place. Some of these recommendations were not followed for reasons discussed in following sections.

PMP Organizational Structure

Personnel from CDF, DFG, DMG, SWRCB, and the RWQCB were major participants in the PMP. The major components were the instream component and the hillslope component. The latter included implementation monitoring, effectiveness monitoring (Table 1), and a geologic element. Each of these components is discussed in more detail in following chapters. The work plans, status reports and final reports of these components were subject to an external scientific review to help ensure their acceptability. The PMP's organizational structure closely corresponded with the funding and contractual arrangements provided by CDF.

PMP Time Frame

The PMP field work encompassed two field seasons, beginning in June 1993 and continuing through December 1994 (Figure 2).

Funding and Contributions

Finding funding, expertise, and personnel to conduct the PMP was a major task of MSG. The Clean Water Act Section 319 grant monies provided by USEPA through SWRCB were the major source of funding for the CDF contractor for the hillslope component. The CDF monitoring monies were used largely for contracts (see Appendix). The largest of these was with DFG to carry out the instream component of the PMP. Other CDF contracts provided for a general manager for the PMP, for external scientific review, and for the geologic element.

To a large degree, the PMP was made possible by in-kind contributions of resources and good will. CDF, DFG, and the RWQCB contributed countless hours of staff time and expertise. Landowners also contributed generously to the PMP. They gave PMP personnel legal permission and physical access to work on their properties, shared detailed maps and aerial photographs needed to select and find sampling sites, and they often provided transportation, personal guidance, and coordination to support PMP personnel in the field.

PMP Products

- A final report prepared by DFG, dated December 20, 1995, and entitled, "Board of Forestry Pilot Monitoring Program: Instream Component" (Rae, 1995).

- An instream monitoring training curriculum (that largely evolved into the curriculum for the initial Watershed Academy at Humboldt State University during August and September 1995).

- A functioning database established in DFG for storing, analyzing, and reporting PMP and LTMP instream monitoring data.

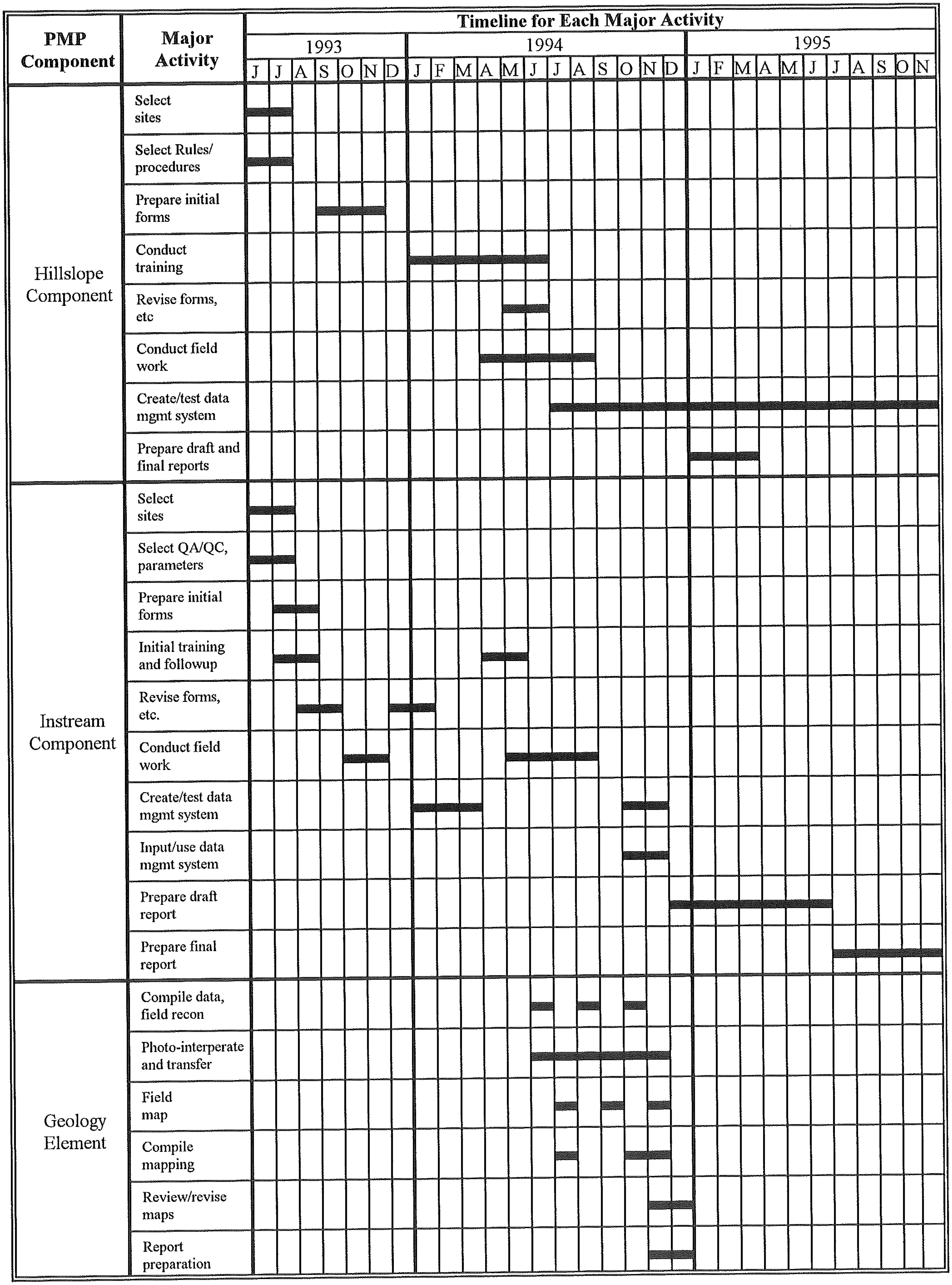
- A final report prepared by Dr. Andrea Tuttle, dated March 1, 1995, entitled, "Board of Forestry Pilot Monitoring Program; Hillslope Component" (Tuttle, 1995), including a set of field forms and instructions for use.

- A database established by CDF's Fire and Resource Assessment Program (FRAP) for storing, analyzing, and reporting PMP and LTMP hillslope monitoring data.

- A final report prepared by Thomas Spittler, dated 1995, and entitled, "Pilot Monitoring Program: Geologic Input for the Hillslope Component" (Spittler, 1995), with accompanying maps of selected PMP watersheds.

- o A final report by Dr. Don Erman, Nancy Erman, and Ian Chan dated January 22, 1996 and entitled, "Pilot Monitoring Program: Review and Final Recommendations Prepared for the Monitoring Study Group" (Erman, *et al.*, 1996).

Figure 2. Summary of PMP Timelines



CHAPTER IV.--SELECTION OF TIMBER OPERATIONS FOR PMP FIELD TESTS

General Objectives for PMP Site Selection

The general objectives of PMP site selection were as follows:

1. To help ensure that the field testing was conducted under a range of conditions likely to be encountered during the LTMP by selecting sites scattered throughout the State's major timber producing areas.

2. To make the PMP more efficient and to facilitate coordination of hillslope and instream components by using the same site for both components as often as feasible.

3. To facilitate testing of the instream monitoring procedures' abilities to detect a "signal" (i.e., an instream change associated with a timber operation) above the "noise" (i.e., instream changes resulting from other factors) in the watershed.

4. To help ensure that sites would be worth visiting by selecting locations where forms and procedures for the most important Rules/BMPs could be tested.

Practical Restrictions on Site Selection

Large Ownerships

Although several landowners were very helpful, they all had concerns about allowing PMP activities on their lands. These concerns included the following:

1. The risk of accidents or injuries involving PMP personnel on their lands, their ability to respond in a timely manner to such situations, and the possible consequences thereof.

2. The increased risk of enforcement actions being taken on problems found on their land.

3. The risk of subsequent adverse use by outside parties of PMP data obtained from their lands.

To reduce the time and effort involved in obtaining access permission from many landowners, MSG decided that the PMP would be conducted only at sites in large industrial timberland holdings.

Closed Timber Operations

CDF decided that all PMP field activities would be restricted to closed timber operations (i.e., those for which CDF had approved a notice of completion). This restriction addressed landowner concerns by eliminating the threat of CDF enforcement activity and allowing a landowner to know exactly where PMP personnel would be on their lands. This meant that: (a) implementation monitoring approaches could not be tested for those Rules/BMPs for which evidence of implementation would be present only during a timber operation (e.g., rutting of roads), and (b) most good locations for testing instream procedures (especially for sediment) would be unavailable, because optimum stream reaches for monitoring are limited in extent and may not be associated with timber operations. On the other hand, MSG believed that the tradeoff was worthwhile because it was believed that a sufficient number of suitable stream reaches should still be available.

Target Watersheds

With the limited time and staff resources available for the PMP, MSG decided that visiting 30 timber operations would be feasible only if the locations were concentrated into a few target watersheds. This would reduce the expenditures of time and money that would otherwise be incurred by making long trips to single sites widely scattered around the State. MSG decided that any resulting bias of the sample population was acceptable for the PMP, because it was not intended to reach any conclusions regarding implementation, effectiveness, or instream effects. To help ensure representativeness, MSG also decided that the target watersheds should be located on the western side of the Sierra Nevada, in the Klamath Mountains, and in the Northern to Central Coast Ranges.

Selection Criteria for Target Watersheds

MSG decided that any candidate watershed must meet the following criteria to be deemed suitable for the PMP:

1. Its characteristics should be generally representative of the timber-producing areas of the geomorphic province in which the watershed is found.

2. Its timberlands should be largely under the ownership of a single company to simplify access and logistical considerations.

3. It should contain at least five, and preferably 10, suitable timber operations to allow for logistical efficiency.

Selection Criteria for Individual Timber Operations

General Criteria

MSG decided that any candidate timber operation must meet all of the following criteria to be deemed suitable for either the hillslope or instream component:

1. It should have been conducted under the most recent watercourse and lake protection Rules/BMPs (adopted by BOF in October 1991) to avoid dealing with differing sets of Rules/BMPs.

2. It should have been through at least one winter season since the conclusion of soil-disturbing activities (e.g., construction of roads, skid trails, and/or landings; yarding; and/or mechanical site preparation) to help ensure that the effectiveness of Rules/BMPs had been tested by storm events.

3. It should include at least one half mile of newly constructed or reconstructed logging road and/or a harvest area at least 10 acres in size to help ensure an adequate opportunity for testing: (a) the hillslope component's forms and approaches for a wide spectrum of important Rules/BMPs, and (b) the instream component's ability to detect instream impacts.

4. It should include at least one Class I or Class II watercourse within or immediately adjacent to the area of harvesting, logging road work, and/or site preparation to help ensure adequate opportunity for testing: (a) the hillslope component's forms and approaches for the new watercourse and lake Rules/BMPs, and (b) the instream component's ability to detect instream impacts.

5. It should be safely accessible by vehicle.

MSG decided that no criteria for Class III or Class IV watercourses were needed. Class III watercourses are so abundant as to be unavoidable, and there are few standard practices for Class IV watercourses.

Instream Criteria

To be deemed suitable for the instream component, MSG decided that, besides meeting the preceding criteria, the Class I or Class II watercourse(s) within or immediately downstream from each timber operation should meet the following criteria:

1. It should be a perennial stream to ensure that macro-invertebrate monitoring parameters and some sediment-related parameters could be used.

2. It should be safely wadeable and feasible to work in at most locations from late Spring through Fall.

3. To allow testing of the sediment-related parameters, it should: (a) have an average gradient (as determined from 1:24,000 maps) between one and five percent over a distance of at least 1000 meters; (b) have at least six pools, three riffles, and three runs; and (c) not be so large as to mask or obliterate changes which might be associated with a timber operation.

4. It should be safely and feasibly accessible by vehicle and on foot.

Random and Stratified Random Selection

MSG (1993) recommended that final selection of suitable candidate timber operations be carried out using a random selection process to reduce bias. As part of the PMP, MSG planned to test a random selection process similar to that used during the FPRAT study. However, due to the small number of candidate timber operations that met the selection criteria, MSG had to use all suitable candidates. Therefore, a random selection process was not developed or tested during the PMP. This was considered acceptable for the PMP due to its limited goals and objectives.

The forest practices most strongly associated with significant water quality problems occur primarily in relatively rare situations (e.g., logging roads, landings, or skid trails on very steep, highly erodible, or unstable slopes or immediately next to watercourses or lakes). Use of a purely random site selection process could easily have resulted in no LTMP tests of the hillslope component procedures for those relatively rare, but very important, conditions. Therefore, MSG (1993) also recommended that candidate timber operations be stratified by the relative degree of risk that they pose, and that a stratified random selection process be used to ensure that predetermined proportions of timber operations representing high-risk, moderate-risk, and low-risk conditions be included in the sample population.

During the initial phases of the PMP, MSG members attempted to assess the relative degree of risk of erosion and sedimentation posed by different timber operation sites. Making a reasonable risk assessment was usually not possible, however, because CDF's THP information rarely identified a risky situation unless additional information was included for a proposed nonstandard practice. The risk assessment approach was amended for the PMP to use only available generalized knowledge of geologic, geomorphic, and climatic factors. Due to the small number of timber operations that were finally deemed suitable, they were all selected without risk-based stratification. Briefly put, the PMP took what it could get.

Selection Process for Target Watersheds and Timber Operations

The selection process for target watersheds was interwoven with that for timber operations. MSG members began by canvassing the owners of large timberland holdings to learn who would be willing to allow PMP activities on their lands and suggest candidate target watersheds and timber operations in their holdings. Landowners were assured that: (a) they would not be subject to enforcement actions should problems be found during PMP activities, and (b) the PMP information would be reported in a manner that minimized their risk of subsequent adverse use by outside parties. Several timberland owners responded positively to this inquiry. Landowners and MSG members cooperatively identified several watersheds that initially appeared to meet the selection criteria. These candidate watersheds included the Mokelumne River in the central Sierra Nevada, the Scott River and Trinity River in the Klamath Mountains, and the Noyo and Gualala Rivers in the Northern Coast Ranges. Landowners and CDF personnel identified timber operations in each of these watersheds that initially appeared to meet timber operation selection criteria. On further review, the Trinity River watershed was dropped because none of the available candidate timber operations in that watershed met the selection criteria.

In August 1993, CDF field offices compiled and sent to MSG their available THP information for each of the 64 remaining identified candidate timber operations. Based on the available THP information, MSG members categorized each of the candidate timber operations as clearly unsuitable, apparently suitable, and uncertain.

CDF's THP information often did not allow a clear determination of candidate site suitability, particularly for the instream component. Therefore, MSG members requested more information from both CDF field offices and landowners to validate the suitability of the candidate timber operations that were not clearly suitable. The landowner's responses were very helpful; MSG members were allowed to view detailed maps and aerial photos in company offices. This step of the review showed that none of the available candidate timber operations in the Scott River watershed were suitable for the instream component. Consequently, much later during field testing, DFG and a landowner found one other stream reach (not associated with any timber operation) for the instream component on Cottonwood Creek in the Klamath Mountains. Similarly, later during field-testing CDF added two timber operations to the hillslope component; one in the Burney area and one in the American River watershed.

As a final step, in the Mokelumne River and Gualala River watersheds, DFG and landowners worked together to field check the suitability of candidate timber operations for the instream component. More detail is set forth in Rae (1995).

Results and Discussion

CDF THP information was initially submitted and reviewed for 64 candidate timber operations. For the hillslope component, 30 of these were eliminated in the initial office review, an additional eight were eliminated during review of landowner information, and seven were eliminated during field review. Nineteen of these timber operations were finally deemed suitable for the hillslope component. For the instream component, 29 candidate timber operations were eliminated in the initial office review, an additional 13 were eliminated during review of landowner information, and 12 more were eliminated during field review. Only ten candidate timber operations ended up being suitable for the instream component (and some of those were marginal).

The general locations of the timber operations visited during the PMP are shown in Figure 3.

CDF THP information often did not include the information needed to confidently determine that a candidate timber operation: (a) was complete and had been through a winter since completion of operations, (b) was still feasibly and safely accessible by vehicle, (c) represented one or more high-risk situations, or (d) met instream selection criteria. The first two deficiencies were a major source of uncertainty regarding timber operation suitability for both PMP components, and required MSG members to expend considerable time and effort obtaining the necessary additional information.

Using CDF THP information, MSG members could determine that a timber operation was suitable for the hillslope component with only fair accuracy and could not do so at all for the instream component. Reviewing landowner information (especially when dealing with a cooperative large landowner) was an effective way to aid in ranking timber operation suitability for both components. Using landowner information, MSG members could much more accurately determine that a timber operation was suitable for the hillslope component and/or was unsuitable for the instream component because: (a) the stream reach(es) could not be safely and feasibly accessed by vehicle, and (b) stream gradient and flow would be unlikely to meet selection criteria. A field review did not significantly change the accuracy with which MSG members could determine that a timber operation was suitable for the hillslope component. Yet, a field review was almost always needed to confidently determine that a stream was suitable for the instream component, especially regarding the type and number of pools and riffles needed for testing sediment-related and macro-invertebrate monitoring parameters.

It was difficult to find a timber operation that had been conducted under the recently promulgated Rules/BMPs, was closed, and had been through at least one winter since the completion of operations. This was a major reason for the number of candidate timber operations that were unsuitable for the hillslope component; it is not likely to be repeated during the LTMP.

It was very difficult to find timber operations where streams met the selection criteria for accessibility, gradient and flow, and contained the necessary pools, riffles, and runs, especially for sediment-related parameters. It would take a very major, difficult, and costly upgrading of CDF THP information to make a significant improvement is this area.

Restricting instream monitoring to timber operations overly restricted the ability to find suitable instream sites, especially for sediment-related parameters.

MSG members could not apply a risk assessment that might have allowed more meaningful stratification of timber operations. Making the changes in the THP form needed to simplify risk assessment would be relatively easy. Without such changes, risk-based stratification may not be an effective tool.

Several high-risk timber operations that were suitable for the hillslope component were not suitable for the instream component. This is not surprising, because timber operations that are associated with a high sediment risk are often in steep headwater areas characterized by steep stream gradients and by bedrock and/or boulder channels. Monitoring most sediment-related parameters in such areas is usually not feasible, because introduced sediment is usually flushed through the stream system and does not leave much evidence of its passing.

Figure 3.--General Locations of Timber Operations Visited During PMP

June 20, 1996
Prepared by Coast-Cascade GIS

CHAPTER V.--SUMMARY OF THE INSTREAM COMPONENT

Introduction

A detailed description and discussion of the instream component are contained in Rae (1995). This chapter contains only a brief summary of the monitoring parameters and protocols, QA/QC protocols, training program, data management system, results, and refinements described in that report. Chapter VIII presents the major lessons learned during the PMP instream component.

Goals

The overall goals of the instream component were as follows:

1. To begin development of a "tool box" or "menu" of instream monitoring parameters and related QA/QC protocols for the LTMP:

   a. Whose effectiveness, reliability, and feasibility had been tested and verified by the State for use in monitoring in forested watersheds;

   b. That could be confidently used within the range of effectiveness explored during the PMP; and

   c. That could be used to establish consensus-based standard operating procedures with appropriate levels of reliability, compatibility, and consistency between different watersheds and users in terms of: (1) the parameters monitored, (2) the conditions under which they are applied, (3) how they are applied, and (4) the resulting sets of data.

2. To develop a training program and materials, both for the LTMP and for other parties, which could prepare people to carry out the tested monitoring protocols and QA/QC procedures for the LTMP efficiently and correctly.

3. To develop an analytical testing and decision-making process that could be carried forward to continue making additions to the toolbox.

4. To develop a database management system for instream monitoring programs.

General Objectives

The general objectives of the instream component were:

1. To select and test instream monitoring procedures considered likely to be useful under the range of conditions found in the State's forested watersheds.

2. To develop and test selection and location procedures for specific monitoring sites.

3. To develop and test forms, manuals, and QA/QC protocols for: (a) locating and relocating sampling sites, (b) describing sampling sites, (c) conducting field sampling and sample handling, and (d) taking, recording, and verifying measurements and field data.

4. To develop and test a data management system and protocols for efficient and effective entry, verification, cleanup, storage, retrieval, analysis, and reporting of data.

5. To develop and test a training program and materials to prepare field personnel to carry out the selected instream monitoring approaches efficiently and correctly.

6. To review and evaluate the effectiveness, reliability, cost, and feasibility of each of the preceding items, as implemented, and make recommendations for appropriate changes.

Selection of Monitoring Parameters and Protocols

Selection Criteria

Following MacDonald, *et al.* (1991), MSG adopted criteria for selecting quantitative instream monitoring parameters to be tested during the PMP. The preferred parameters rated highly against all or most of the following criteria and low against none of them:

1. Cold water fisheries and potable water supplies (which are usually the most sensitive beneficial uses of waters derived from forested watersheds) should be sensitive to changes in the parameter.

2. It should be sensitive to disturbances caused by timber harvesting and logging road construction and maintenance. (Pesticides and fertilizers were not included because BOF has no jurisdiction over their use.)

3. It should have a confidence factor of about 90 according to the "Parameter Selection System for Streams in Forested Areas" developed by MacDonald.

4. To simplify sampling, analysis, detection of significant changes, and correlation, its natural range of spatial and temporal variability should be low, so that its variability will not mask the effects of timber operations.

5. It should represent the overall condition of a stream reach and the way in which it responds to disturbance, not just a "snapshot" of a passing condition.

6. Reasonable temporal or spatial controls should be available, either from existing information or by establishing them for the project.

7. The hazards, frequency, cost (in terms of staff time, funds, expertise, equipment, and access), and difficulty (in terms of equipment, timing, access, and QA/QC protocols) of data collection, sampling, analysis, and interpretation should be relatively low to moderate.

8. It should be capable of providing reliable and reproducible results.

9. It should be widely applicable and useful.

10. It should be in a category recommended by MSG (1993) (i.e., temperature, pool parameters, bed material size and sorting, riparian vegetation, and large woody debris).

Parameter Selection

MSG members reviewed available literature and consulted experts to determine likely candidate parameters. The following were considered the most likely candidates (the relevant literature citations are set forth in Rae (1995)):

1. V*--an index of the relative volume of a pool filled by annually mobile fine sediment.

2. Riffle Armor Stability Index (RASI)--an index of the relative size of the largest riffle bed particles that moved during the most recent bank full flows.

3. D_{50}--the median diameter of riffle gravels.

4. Macro-invertebrates--sampled and assessed using the California Stream Bioassessment Procedure and a variety of bioassessment metrics/indices.

5. Temperature--instantaneous measurements with both hand held thermometers and continuous measurements with recording sensor (Hobo™) units.

6. Large woody debris--using techniques identified in MacDonald, *et al.* (1991).

7. Riffle sediment deposition--using installed collection boxes and procedures developed by Vyverberg.

The actual process for selecting instream monitoring parameters was fairly subjective. Although the selection criteria were not all of equal importance, they were not formally weighted relative to each other, and the parameters were not formally scored against each criterion. MSG selected all but two of the candidate parameters as **PMP parameters.** The Vyverberg technique was rejected because it required considerable setup and calibration and also frequently repeated site visits. Large woody debris was rejected because no quantitative method was discovered which seemed likely to yield data about the effectiveness of the current Rules/BMPs. To help establish the larger context within which the quantitative monitoring was being conducted, MSG members also decided to use a level II inventory of habitat types, channel typing, photo documentation from established reference points, and detailed site descriptions. This was the part of the instream component in which MSG was most active as a group.

The remainder of the instream component was carried out primarily by DFG pursuant to the contract with CDF. With selection of each of the PMP parameters, DFG could identify related needs for field sampling, field measurement, data handling, QA/QC protocols, monitoring site selection criteria, and reference information, although these continued to evolve throughout the PMP. During the second field season, DFG added riparian canopy measurements by spherical densiometer, sighting tube, and Cruz-All.

Instream Component Personnel

MSG has determined that a wide spectrum of persons should be included in the LTMP to help ensure that: (a) monitoring costs to the State agencies are reduced, and (b) all interested parties get a chance to participate and to develop a sense of confidence and ownership in the LTMP process and results. Therefore, MSG initially considered including a broad spectrum of people in the instream component field crew(s), including representatives from forestry organizations and environmental organizations. The purpose for this would have been to obtain their early involvement and input and to evaluate the differences in training needs, abilities, and performance among the various categories of representatives. MSG decided not to pursue this option during the PMP, because: (a) the added variability would have made it much more difficult to evaluate the relative importance of all the other variables involving personnel and training, and (b) it would have significantly increased liability and access issues.

MSG preferred an approach that would not require high levels of involvement by experts. This was preferable for the following reasons: (a) to ensure the persons involved in the planning, review and approval of THPs could benefit by participation in the LTMP, and (b) to keep the overall cost and complexity of the LTMP to the minimum that would provide the quality of information needed by the state agencies and other interested parties. Therefore, MSG chose not to use professional consultants or some of the higher-powered agency experts during the PMP, but to evaluate the use of trained technicians working under the immediate field supervision of an experienced supervisor.

Summary of QA/QC and Training Programs

The immediate objective of the QA/QC program for the PMP instream component was to ensure the highest feasible quality of PMP instream data; that of the training program was to teach the field crews (including the field supervisors) how to carry out the PMP parameters correctly. The long term objectives for both were as follows: (a) to review the feasibility, efficiency, and effectiveness of the training program and materials and of the selected QA/QC procedures and protocols and to revise them as needed during the PMP, and (b) to prepare a final training manual and curriculum, field reference materials, and a QA/QC manual for future use during the LTMP and by other interested parties.

The DFG Project Manager, in consultation with experts regarding each of the selected parameters, compiled and created initial versions of training manuals, field reference materials, data forms, instructions, and other QA protocols to ensure that site locations, site descriptions, sampling, measurements, data entry, and field management of data was done in a secure, comprehensive, integrated, and consistent manner. (For example, stream reaches were to be sampled working upstream so that macro-invertebrates would not be disturbed before they could be sampled.) In addition, the QC procedures to be used by the Project Manager and field supervisors were worked out and specified. Selection and development of the QA/QC procedures and protocols were intimately involved with development and implementation of the training program.

The initial training sessions included both academic instruction and hands-on field training conducted by DFG with the assistance of monitoring experts. Following the initial training session, the field crews helped in revising the materials to make them more clear, concise, organized, integrated, comprehensive, and easy to use. Field work began immediately following these revisions, and the revised materials were used throughout the 1993 field season. At the end of that season, the field crews again met with DFG managers to make further refinements based on their first season's field experience. Similarly, in 1994, another training session was held for old and new field crew members using the recently revised materials, and the field crews again met with DFG managers to make additional refinements at the end of the field season.

Some errors and omissions were detected in the instream data during each field season. When this became evident through review of data forms, data collection was suspended until focused on-site training sessions were conducted by the DFG Project Manager and field supervisors.

The training materials were also used as the basis for some of the curriculum presented at the initial version of the Watershed Academy held at Humboldt State University in August and September 1995. Portions of the field manual evolved into Rae (1995), Appendices C, D, E, F, and H.

Locating Specific Stream Reaches and Sampling Sites

To use the PMP monitoring parameters appropriately, PMP stream reaches needed to meet a very specific set of criteria for length, gradient, flow, and structure. In addition, it was preferable for a PMP stream reach to not have been subject to any effect so great that it could overwhelm the monitoring results (e.g., upstream water diversion, road crossing or landing failure; midreach tributary confluence). Stream reaches that did not satisfy these conditions were generally not worth using to test the PMP parameters. The need to meet so many conditions is a major reason: (a) there was so much uncertainty regarding the suitability of a timber operation for the instream component, (b) a field visit was always needed to verify stream reach suitability before the arrival of the field crew to begin work, and (c) the number of timber operations suitable for the instream component was so much lower than the number suitable for the hillslope component.

To ensure that a PMP stream reach had the greatest possibility of showing an effect from a timber operation (and to test the detection ability of the PMP parameters), the upper end of each reach was located immediately downstream (or as close to there as access constraints would allow) from the most downstream point at which disturbances caused by the timber operation might affect the stream.

Each stream and any significant tributaries were inspected upstream from the upper end of the PMP stream reach for a cumulative distance of 1000 meters. Thus, the feasibility of having established a suitable **control stream reach** can be evaluated. A stream reach suitable as an upstream control for the full set of PMP monitoring parameters was found in only four cases. If the stream reach selection criteria had been relaxed to address only one or two of the PMP parameters, suitable upstream control reaches would have been found in more cases. Application of the PMP parameters is most appropriate and safe in smaller, safely wadeable stream reaches. In the Mokelumne River watershed and in the Noyo River area, safely wadeable streams occurred mostly in the upper portion of the watershed where the required low stream gradients occurred only rarely and in short reaches.

To ensure that the correct stream reach could be relocated during subsequent PMP site visits (and to test the reliability of various marking techniques), a point that would not be obliterated by either flooding or timber operations was marked permanently (usually with rebar) and visibly (usually with colored flagging), its coordinates were recorded using Global Positioning System (GPS) technology, and the distance and bearing to the upper end of the PMP stream reach were recorded.

CHAPTER VI.--SUMMARY OF THE HILLSLOPE COMPONENT

Introduction

A detailed description and discussion of the hillslope component are contained in Tuttle (1995). This chapter contains only a brief summary of the monitoring parameters and protocols, criteria and methods, QA/QC methods, training program, data management system, results and refinements. Chapter VIII presents the major lessons learned from the hillslope component.

Goals and Objectives

The overall goals and objectives of the hillslope component were very similar to those of the instream component, except that the monitoring approaches focused on identification and evaluation of: (a) sampling site conditions, (b) field **features** and **problems**, (c) Rule/BMP implementation, and (d) Rule/BMP effectiveness in keeping soil on the hillslope and shade over watercourses. Another goal was to develop monitoring approaches that provide as much quantitative information as possible, yet are practical to apply.

Selection of Rules/BMPs to be Monitored

Following an MSG (1993) recommendation, the MSG members and Dr. Tuttle reviewed the Best Management Practice Evaluation Program developed by USFS Region 5 as a model for the PMP hillslope component. The USFS forms and approaches required substantial changes to be used by the State. The primary changes were as follows:

1. Additional site information was collected to test the ability to identify and evaluate the contribution of site conditions to observed problems.

2. The effectiveness evaluation procedure was more intensive, applying to every feature, not just those associated with observed problems.

3. Effectiveness was evaluated wherever each relevant Rule/BMP was implemented, because the State's regulatory Process is much more Rule-driven than that of USFS.

CDF staff, MSG members, and Dr. Tuttle reviewed each of the approximately 1300 Rule/BMP provisions (some Rules have more than one provision, and some provisions occur in more than one Rule) that relate in some way to water quality protection. They categorized these Rules/BMPs as follows: (a) administrative requirements related to THPs, RPF and LTO responsibilities, and CDF inspections and reports; (b) general intent statements and performance standards, (c) prescriptive operational standards that apply to the timber operation as a whole or that are too subjective (e.g., "minimize", "reduce"); (d) prescriptive operational standards that can only be evaluated during an operation because no evidence remains after that (e.g., fill placement and compaction); and (e) prescriptive operational standards that can feasibly be quantitatively evaluated in the field after completion of operations.

The last category contained 154 Rule/BMP provisions and was the only one for which quantitative monitoring was deemed to be feasible during the PMP. These Rules/BMPs were further subdivided into the five subject areas considered by the BEAC to have the strongest association with water quality impacts, that is: logging roads, landings, skid trails, watercourse crossings, and activities within a Watercourse and Lake Protection Zone (WLPZ).

Development and Testing of Hillslope Monitoring Approaches

Random Transect Approach

Based on the results of these reviews, CDF staff and Dr. Tuttle developed two different approaches to test during the PMP. The first, the "random transect approach", involved semi-quantitative/categorical evaluation of the 154 operational Rule/BMP provisions for which quantitative monitoring was feasible following timber operation completion. The goals in developing this approach were: (a) to remove subjectivity wherever practical; (b) to provide repeatable results when carried out by trained evaluators; (c) to provide enough information to understand the conditions under which problems do, or do not, occur; and (d) simplify use by field personnel and data entry operators.

Applying the transect approach to an entire timber operation would consume a great deal of time and resources, so the approach sampled 1000-foot-long transects along roads, skid trails, and WLPZs. The transects were keyed to one or more selected landings within a timber operation. From a marked reference point at the landing, the distance along the transect to each observed feature and/or observed problem was recorded. At each feature and/or problem, any observed problem was identified and rated, and the effectiveness of each applicable Rule/BMP was rated. Implementation was rated only at each observed problem and again for the transect as a whole. The data produced by the approach is mostly **categorical**.

Whole THP Approach

The random transect approach is likely to miss the relatively rare, but most critical, erosion sites on any given timber operation, so it would take many years of monitoring to collect enough data to reach supportable conclusions regarding the relative importance of site conditions, implementation, and effectiveness in contributing to observed problems in these situations. Therefore, CDF staff and Dr. Tuttle developed a second approach, called the "whole THP approach". It provides for a more qualitative evaluation of: (a) sites of large erosional events, (b) the 92 Rule/BMP provisions in the general intent statements and/or performance standards category, and (c) categorical evaluation of the entire timber operation, including implementation and effectiveness ratings for harvest planning, timber operations, and post-harvest treatments.

Testing

Due to time and budget constraints, only the transect approach was tested during the PMP, and no approaches for evaluating the other categories of requirements were prepared. Testing and development of the random transect approach were iterative processes. The forms and instructions were revised to improve their clarity, ease of use, and efficiency following each round of testing. Initial field testing was done by the CDF personnel who developed the forms and instructions. Once the transect approach seemed feasible to them, additional CDF staff was trained in its use and tested it under direct guidance and supervision at various locations. These tests were also attended by MSG members, private industry representatives, staff from Review Team agencies, and members of the public. At 17 timber operations, trained, but unsupervised, CDF inspectors carried out the final PMP testing of the clarity, content, and useability of the transect approach forms and directions. Minor changes were subsequently made to ease data entry for the data management system.

Data Management System

CDF's Fire and Resource Assessment Program (FRAP) completed a data management system for the hillslope component in July 1996. To ensure adequate identification of system needs, the database structure was designed in consultation with CDF PMP staff, Dr. Tuttle, MSG members, and DFG database experts. Goals for the data management system included the following:

1. It should be flexible enough to allow identification and evaluation of different generations of Rules/ BMPs (as they continue evolving).

2. It should allow and simplify needed changes in the format and content of hillslope monitoring data.

3. It should help in production of meaningful, reliable data analyses and reports.

4. It should be appropriately linked with DFG's instream monitoring data management system.

Input screens, data entry, structure of queries, and reporting formats have been completed and the PMP hillslope component data has been entered. Currently, the database and the PMP data are being analyzed by statisticians with the USFS, Pacific Southwest Research Station, to develop analytical techniques which can be used for data collected under the LTMP.

Discussion

Preliminary results suggest that the random transect approach is sufficiently clear, complete, and usable to allow the most important Rule/BMP provisions to be effectively and reliably monitored by trained CDF personnel. Training, experience, and a strong commitment to using the approach exactly as specified is critical to successful application. Appropriate categorization of Rule/BMP implementation requires a high degree of familiarity with the Rules and Process.

Some weaknesses in the PMP hillslope data may become evident with the ongoing testing of the hillslope data management system. A test of the variability in responses within and between different types of users (e.g., industry RPFs, independent RPFs, Review Team agency staff, members of the public) has yet to be made. Both tests will probably reveal some needed amendments in currently existing transect approach training programs, forms, instructions, and QA/QC protocols for data collection, handling, entry, and verification.

The tested method of evaluating implementation may make it difficult to eventually decide whether a Rule/BMP is unnecessary (i.e., consistently poorly implemented, but without associated problems even when tested by stressing events). More experience will probably be the best guide in determining whether a more rigorous approach is needed in this area.

The effectiveness portion of the transect approach could be implemented repeatedly over a period of years for any given timber operation to allow a determination of problems (e.g., gullying, shallow-seated landsliding) that may occur only after an extended period and/or in response to a fairly severe climatic event.

The existing transect approach forms and the timing of monitoring would need to be amended considerably to allow evaluation of the Rule/BMP provisions for which there is evidence only during the operation.

The whole THP approach could effectively address some inherent deficiencies of the transect approach, but it has yet to be tested.

Nonstandard practices are one of the most criticized aspects of the program, and they have been identified by FPRAT (1987) and CDF (1995) as being generally less effective in protecting water quality than standard practices. The need to improve the effectiveness of the Process was identified by FPRAT (1987) and Greenwood and Smith (1995). Monitoring approaches to evaluate the implementation and effectiveness of nonstandard practices and various Process elements were begun during the PMP, but could not be completed or tested due to time and resource constraints. Further work is needed in both of these areas.

CHAPTER VII.--SUMMARY OF THE GEOLOGIC ELEMENT

Introduction and Objectives

This chapter is a summary of the information in Spittler (1995). The goal of the PMP geologic element was to determine the degree to which problems identified in the instream and hillslope components were associated with areas susceptible to geologic instability. The objectives were as follows:

1. To map relative slope stability of some PMP target watersheds for comparison with hillslope component results.

2. To map dominant fluvial processes for some PMP stream reaches and watersheds for comparison with instream component results.

3. To evaluate the utility and feasibility of such mapping in other monitored watersheds.

The work included the PMP watershed mapping and geologic mapping for the Caspar Creek Watershed Project, where research level project monitoring has been occurring since 1962. All aspects of the work were conducted by DMG under contract with CDF.

Erodible Watersheds Inventory

The Erodible Watershed Inventory was completed prior to the PMP and modeled the susceptibilities of 10,000 to 50,000 acre watersheds on private and State commercial timberlands to soil erosion, shallow landsliding, and deep landsliding (see Appendix and McKittrick, 1994). To ensure internal consistency, only data with coverage throughout the area being modeled were used. The data included geologic, slope, and precipitation factors derived from regional compilations at scales of 1:500,000 and 1:750,000. A GIS was developed to sum these factors over each entire watershed to define its relative intrinsic susceptibility. This inventory was considered in attempting to assess the relative risk associated with each PMP watershed.

PMP Mapping

The PMP included more detailed geologic and geomorphic mapping and development of more detailed landslide susceptibility maps for the North Fork of the Gualala River in the Northern Coast Ranges and for the privately owned portion of the North Fork of the Mokelumne River in the central Sierra Nevada (McKittrick, 1995a and 1995b). Approximately 35 active and dormant landslides were mapped per 2500 acres in the North Fork of the Gualala River, compared to only five landslides per 2400 acres in the North Fork of the Mokelumne River. This is consistent with the differing geology and geologic history of the two areas and with the modeling results of the Erodible Watersheds Inventory.

The style of landsliding was dependent on bedrock lithology and structure. In the North Fork of the Gualala River, slopes underlain by sandstone have a long history of small debris slides and debris flows. Debris slide slopes dominate the landscape. In contrast, where the bedrock is highly sheared and more clay-rich, landsliding is expressed as relatively deep-seated rotational landslides and earth flows. These findings are consistent with slope stability theory.

Caspar Creek Watershed Studies

Geologic and geomorphic mapping of the North and South Forks of Caspar Creek in Jackson Demonstration State Forest were completed for the long-term research level monitoring projects in progress (Spittler and McKittrick, 1995). This mapping showed that old timber operations (i.e., conducted before the Rules were inacted in 1974) are the dominant factors controlling the incidence and locations of recent shallow landslides. In the South Fork watershed, 63 of 66 active landslides are associated with logging roads and skid trails built between 1967 and 1973. In contrast, in the North Fork watershed, where timber operations were limited between the turn of the century and the promulgation of the Rules, seven recent landslides are related to old logging roads and eight are on natural, generally steep slopes. Changes in forest practices following Rule implementation appear to be responsible for the change in landslide incidence, particularly those related to road and landing design and placement and yarding methods. The intense and long-lasting disturbances caused by older practices can effectively obscure evidence of earlier landsliding due to intrinsic slope instability and more recent practices.

Discussion

Mapping of fluvial geomorphology proved to be infeasible from aerial photographs, and time constraints did not allow field mapping of fluvial geomorphology. Therefore, no comparison with PMP instream results is forthcoming.

PMP hillslope results have not yet been correlated with the PMP geologic results because of the delay in completing the CDF hillslope data management system, as well as time and resource constraints. Such a comparison would help determine the probable value and usefulness of doing similar mapping for the LTMP in cooperative monitoring watersheds with differing intrinsic characteristics and land-use history.

The Erodible Watersheds Inventory cannot identify where the more highly susceptible areas are within a watershed, but the probability of having a high hazard timber operation is higher in a highly erodible watershed. The inventory may be an effective way to decide: (a) whether more geologic mapping at the detail done for the PMP is warranted, especially for cooperative monitoring watersheds and for the watershed assessment portions of SYPs, and (b) the relative level of hazard represented by a timber operation, allowing a stratified random sample of THPs to be generated for the LTMP.

CHAPTER VIII.--IMPORTANT LESSONS AND CONCLUSIONS FROM THE PMP

Introduction and General Lessons

The PMP demonstrated that State agencies and landowners can work together effectively and successfully in conducting monitoring activities.

As recognized by MacDonald and Smart (1993), personality characteristics may be the most important qualifying factor for a person doing instream monitoring. To successfully perform in trying field conditions requires dedication, motivation, objectivity, and a high level of integrity. Without these characteristics, no amount of training and QA/QC will guarantee efficient, reliable, and effective performance.

The PMP gave MSG and others a chance to learn from both our successes and our mistakes. This cannot happen unless both are reported. Rae (1995) and Tuttle (1995) discuss the problems encountered, what was done to correct them, and some inherent remaining issues. Rae (1995) discusses many more problems than Tuttle (1995). The instream component dealt with highly quantitative procedures where data integrity is very important. Therefore, a much more rigorous QC program was instituted to detect and correct data errors and omissions than was used for the hillslope component. Also, the instream component data have been entered into a database and statistically analyzed. As often happens, many data omissions and errors were not detected until this stage. The hillslope component data have been entered into a database, but the statistical analysis has yet to be completed. Thus, we probably have much more to learn about the feasibility and effectiveness of training, of field procedures, the database, and QA/QC for hillslope monitoring.

There is no "cookbook" or perfect set of instream monitoring parameters and protocols. For a given set of issues, stream gradient, bed type, etc., some parameters will be more relevant or will better indicate current instream conditions and trends than others. Tradeoffs and the exercise of judgement will always be necessary in determining what should be monitored, how and where it should be monitored, and how the data should be analyzed, interpreted, and reported. For the LTMP, instream monitoring parameters and protocols should be carefully chosen for the situation to be monitored, and monitoring a combination of parameters is likely to provide a better understanding than relying on a single parameter.

Site Selection

Even the categorical/semi-quantitative effectiveness and implementation monitoring procedures tested in the PMP are too time-consuming and tedious to be used on every timber operation. Random selection of a small subset of timber operations would be an effective way to deal with this problem. However, using this selection approach, it would probably take a very long time to: (a) accumulate enough LTMP monitoring results for relatively rare, but high risk situations (e.g., operations on very steep slopes, extremely erodible soils, unstable slopes, or operations in sensitive near stream areas), or (b) reach any conclusions about the effectiveness of the Rules/BMPs that apply to these situations.

A risk-based stratified selection process may be an effective way to deal with this problem. A reliable method for assessing the risk posed by a timber operation is yet to be developed and tested. CDF THP information rarely identifies a high-risk situation unless a nonstandard practice is proposed. Making the changes in the THP form needed to simplify risk assessment and make it an effective tool for the LTMP would be relatively easy. However, beginning to make such changes may be premature until an appropriate risk assessment method has been validated. The Erodible Watersheds Inventory may be an effective way to assess risk for the LTMP, but this approach is yet to be validated.

CDF THP information is usually inadequate to determine confidently whether a particular timber operation: (a) meets selection criteria, (b) represents a high-risk situation, (c) is complete, and (d) that vehicle access is still feasible. The latter two deficiencies can be a major source of uncertainty regarding timber operation suitability for hillslope monitoring. Review of landowner information (especially when dealing with a cooperative large landowner) can be a cost-effective way to improve the efficiency of selecting timber operations for both hillslope and instream monitoring. On the other hand, field review is not cost effective in determining the suitability of timber operations for hillslope monitoring, but is essential for instream monitoring. For LTMP hillslope monitoring, it would be most efficient to eliminate a candidate timber operation from further consideration if: (a) it does not seem suitable from review of CDF THP information and follow-up review of landowner information is not feasible or desirable, or (b) it does not seem suitable from review of landowner information.

CDF THP information will rarely allow a confident determination that a stream reach is safely and feasibly accessible or that other stream factors, such as gradient, stream flow, or stream structure (e.g., pools and riffles) meet the criteria needed for meaningful application of the sediment-related PMP parameters. Landowner information will usually help to resolve all but the last factor. It would take a major, difficult, and costly upgrading of CDF THP information to make a significant improvement for instream monitoring, and the effort is not likely to be worthwhile for the LTMP.

The stream conditions needed to effectively monitor the sediment-related PMP parameters are more restrictive than the conditions for the other PMP parameters. Finding stream reaches suitable for monitoring the sediment-related parameters is difficult. It is safe to assume that: (a) a field review will always be needed to assess suitability of a stream reach for using PMP instream parameters (especially for the sediment-related parameters), (b) only a small percentage of stream reaches associated with a randomly chosen timber operation are likely to be suitable, and (c) a vanishingly small percentage of those are likely to have suitable control stream reaches. Therefore, quantitative instream monitoring for sediment is likely to be unrelated to specific timber operations during the LTMP. As recognized by MacDonald, *et al.* (1991), a **source-search** approach to sediment monitoring for specific timber operations may prove to be useful for the LTMP, but such an approach is yet to be tested.

MacDonald, *et al.* (1991) and MacDonald and Smart (1993) conclude that effectiveness monitoring may provide the most feasible and effective alternative (or at least a necessary complement) to instream monitoring in the following situations: (a) in steeper headwater areas, steep stream reaches or in areas of hard rock where it has a better chance of detecting (or approximating) potential impacts from recent timber operations, and (b) where the variation of the feasible instream parameters is expected to be much greater than that of the effectiveness monitoring parameters.

Instream Component

Lessons Regarding PMP Parameters

The PMP did not provide an opportunity to adequately test of all of the PMP parameters due to the restriction of PMP stream reaches to closed timber operations. Contrary to expectations, this restriction: (a) severely limited the number of available stream reaches, (b) did not allow the PMP parameters to be tested at the most suitable places in each watershed, and (c) caused a significant percentage of the sampling locations to be in marginal stream reaches, especially for sediment-related parameters. It would be useful to further evaluate the limitations, ranges of acceptable values, and refinements of the PMP parameters. Similarly, it would be useful to test the utility, feasibility, and effectiveness of other parameters and protocols. These tests could be carried out in additional study reaches, through communicating with other parties who are also carrying out instream monitoring in California's forested watersheds, and/or through establishment of cooperative State agency/private monitoring programs in certain watersheds.

Sediment-Related Parameters

Of the sediment-related parameters, the PMP found D_{50} to be the most objective and widely useful. It showed the most logical correlations between years, between stream reaches, and with other parameters. It can be quickly, efficiently and effectively used where point bars or riffles can be easily reached.

RASI is also relatively quick and easy to use, but it is more subjective and qualitative than D_{50}; the correlations between years, between stream reaches, and with other parameters are less readily apparent. It is not useful in steep bedrock or boulder channels, nor is it likely to be useful in watersheds where there is abundant silt, clay, boulders and cobbles, but little sand and gravel. It needs further testing before widespread application.

The V* parameter takes considerable time and effort to carry out, and it is useful under a more limited range of conditions. These are as follows: (a) the geologic setting must produce an abundance of fine sediment as opposed to gravel and larger material (which the probe cannot penetrate), (b) the fluvial setting must be a response reach with a gradient of 4 percent or less, and (c) the fine sediment must be annually mobile. It is not useful in steep bedrock or boulder channels, or in areas of hard rock. The determination of the "armor layer" at the base of the annually mobile fine sediment is sometimes subjective. There are significant inconsistencies in the results of statistical analyses of PMP V* data that cannot be attributed to readily discernable causes. While use of the parameter is feasible, it may not be efficient or effective unless used by experienced field crews in stream reaches that meet the given conditions and until more objective methods of determining armor layer depth are established.

Macro-invertebrates and Bioassessment

Macro-invertebrate monitoring is a very promising and effective technique for assessing instream biological health, but it is still being refined for use in California, and no standard for sampling and analysis has been formally adopted across State and federal agencies in California. The PMP found that macro-invertebrate sampling can be conducted quickly and consistently using DFG's California Stream Bioassessment Procedure which is the closest approximation to a formal State standard.

Laboratory analysis is necessary to develop meaningful macro-invertebrate metrics, and it is fairly expensive (about $100 per sample). Developing meaningful interpretations from samples is relatively easy where: (a) knowledge of land use and environmental variables is adequate, (b) metric scores are similar from similar situations, and (c) metric scores vary directly with human disturbances. Use of smaller samples (100 individuals) may often yield reliable metrics. Yet for any given case, it would be prudent to test whether larger samples (300 individuals) significantly improve metrics for a given season and stream reach before settling for the smaller sample. The following metrics appear likely to be useful in most forest situations: taxa richness, diversity index, and EPT index (i.e., total number of taxa within the orders Ephemeroptera, Plecoptera, and Trichoptera). The usefulness of the following metrics is questionable in forest situations: biotic index (an indicator of organic pollutants) and dominant taxa (due to high variability).

Temperature

Temperature can be easily measured in almost any stream reach. It can be used effectively if the measurement objective is carefully defined and relevant variations in stream hydrology (e.g., underflow, inflow, and thermal stratification) and biology (e.g., life cycle needs and sensitivity) are clearly recognized. In contrast with the experience of most users of electronic temperature sensors on the North Coast, many sensors failed during the PMP. The housings of expensive recording Hobo[tm] units frequently failed, and internal condensation in very cold water caused short circuits. Hand held electronic sensors also failed. Where limited data are acceptable, or frequent repeat site visits are feasible, hand held max-min thermometers may be the most reliable and cost-effective instruments.

Canopy-Related Parameters

The PMP techniques used to measure canopy-related parameters are simple and quick to use. They address the degree of canopy coverage or density of riparian vegetation, but do not directly address the amount of stream insolation or stream shading. For stream temperature issues, the Solar Pathfinder[tm] technique is likely to be more useful and relevant.

Other Parameters

Consistent with the results reported by Azuma and Fuller (unpublished), the level II habitat typing and the physical/habitat evaluation procedures used in the PMP are too subjective and inaccurate to be used as instream monitoring tools by themselves, but they are useful in describing a site and setting the context for other monitoring parameters.

QA/QC Lessons

The PMP instream component showed the critical role that QA/QC plays, both in its successes in catching incorrect or incomplete field data and in its failures to catch some of them before they caused significant costs, delays, and inefficiencies. Similarly, it demonstrated how data can be lost or confounded once it gets into an office data management system. More work is needed to ensure that: (a) LTMP instream data problems are effectively prevented, detected and corrected, (b) LTMP instream data are complete and reliable, and (c) LTMP instream monitoring is efficient and effective. The lessons are too numerous to be summarized here, but are detailed in Rae (1995).

Office Data Management System

The capability of the DFG database to manage instream monitoring data from timber operations has not been shown. The DFG database is linked to a geographic information system (GIS), but the PMP database was not linked to the GIS. Initiating that linkage should increase the effectiveness of the DFG database in handling LTMP instream monitoring data. Using nonstandard and incompatible application software packages for data analysis caused considerable difficulty. Data analysis should be conducted with well documented and easy-to-use application software packages. Any custom or proprietary software should have data entry screens, error and range checking, and easily exported and compatible output files. Error and range checking procedures for data entry and analysis should be pertinent to the study and clearly identified and implemented.

Training Program

It is difficult to evaluate the effectiveness of the PMP instream training program, the QA/QC program, or the use of trained technicians given the confounding effects of problems encountered in the PMP. It is likely that the costs of adequate training and supervision were more than offset by the reductions in inconsistent application of field techniques, error rates in data recording, the number of site visits for resampling, and remedying wrong or missing data in preparing for analysis. A clear lesson is that the training must prepare the field personnel for the range of conditions they are likely to encounter.

The instream component also showed that there is little substitute for experience. After a few weeks in the field, field crews could do the work at about twice the originally anticipated rate. Part of this improvement was learning to work efficiently together as a crew. This suggests that LTMP instream monitoring should not use personnel for which there is a high probability of seasonal turnover, transfer, or re-assignment.

Lessons Regarding Project Monitoring

Although desirable, it is not feasible to conduct the type of quantitative project monitoring necessary to fully support the primary objective of the LTMP, i.e., to assess the effectiveness of the Rules, as implemented, in protecting the beneficial uses of water. Fully supporting this objective would require research-level project monitoring combined with research-level effectiveness monitoring. Such an effort would be very rigorously designed, narrowly focused, highly controlled, and very expensive. The research on Caspar Creek at Jackson Demonstration State Forest exemplifies the kind of approach that would be needed. At a statewide level, it is not feasible within the existing financial and institutional capabilities of the involved State agencies.

A major technical problem is the inability to find the suitable spatial or temporal controls required for project monitoring. Using the PMP parameters without controls would be highly inefficient; much effort would be expended for information of a relatively low quality. Suitable controls for project monitoring cannot be established by randomly selecting timber operations that are already completed. Selecting only completed timber operations precludes establishing any temporal control. The PMP has shown that likelihood of finding a suitable spatial control (especially for sediment-related parameters) using a randomly selected timber operation is so small as to be negligible. The use of regional reference stream reaches might help to address this problem, but this is considered unlikely due to the high variability of erosion, sedimentation, and fluvial processes and climatic stressing events within and between watersheds.

Generally speaking, to be suitable for quantitative project monitoring, a timber operation must be designed from the outset (i.e., located, planned, and scheduled) and conducted to serve that purpose. Some of the conditions needed to use the quantitative PMP parameters for project monitoring are as follows:

1. The timber operation must be along a stream reach that has the characteristics needed to be suitable for measuring the PMP parameters; sediment-related parameters will generally be the most limiting and require the presence of response reaches within the project stream reach and any control stream reaches.

2. If the project stream reach is to be used as a temporal control then the timber operation should be delayed for several seasons to allow sufficient monitoring of pre-operational conditions.

3. If spatial control is to be used, then the timber operation must be very near to one or more stream reaches that are very similar to the project stream reach. Suitable control stream reaches may be either upstream from the operation or on another stream.

Combined with effectiveness monitoring and with suitable spatial and/or temporal controls, project monitoring using the PMP parameters (or others that would provide a similar quality of information) would probably, after monitoring many timber operations over several years, allow development of statistical associations (but not scientific or legal "proof") between certain types of changes in instream conditions, certain Rules/BMPs, and certain environmental conditions. The strength of these associations cannot be predicted at this time.

Hillslope Component

Random Transect Approach

For a given timber operation, it is not feasible to quantitatively measure every problem, every feature, or every instance of Rule/BMP application. The PMP appears to have found a combination of techniques that produce a feasible and effective approach for the most significant sets of Rules/BMPs, including those applicable to logging roads, landings, skid trails, watercourse crossings, and WLPZs. First, problem severity and Rule/BMP implementation are not measured directly. Instead, using predefined criteria, they are ranked into several categories ranging from very low to very high, undeterminable, or not applicable. Second, these items are only evaluated along a few randomly selected 1000-foot transects, thereby often providing a small sample of the entire timber operation. Third, implementation is evaluated only where a problem is observed and again for the transect as a whole. The approach assumes that a Rule/BMP is effective where it is properly implemented and no problems are observed. The method for ranking implementation will not allow as confident an evaluation of Rule/BMP provisions that may be unneeded (i.e., repeatedly poorly implemented, but not associated with problems, even after a stressing storm event). The approach can be reliably implemented only by trained personnel who are very familiar with the Rules and committed to exactly following the instructions. This may restrict the scope of the interested parties who could participate effectively.

Whole THP Approach

The random transect approach is likely to miss the relatively rare, but critical, areas of erosion on any given timber operation (e.g., operations on very steep slopes, extremely erodible soils, shallow-seated landsliding, and sensitive near stream areas). The more subjective "whole THP approach" was developed during the PMP to address: (a) implementation and effectiveness of 92 Rule/BMP intent statements and performance standards, and (b) the rare but critical erosion site problem. It may be feasible to expand the approach to address those operational standards that apply generally to a timber operation as a whole or that are stated too vaguely to be quantitatively monitored. This approach would be faster and easier to use for a given acreage, but it was not tested due to PMP time and resource constraints. Results from a whole THP approach would not be statistically valid and would have to be carefully interpreted.

Training and Experience

The hillslope component training program appears to have been effective in enabling CDF inspectors who are already familiar with the Rules/BMPs to work through the forms and instructions solely to evaluate their clarity, content, and workability. The completeness and accuracy of their data entry and responses have not been fully tested yet in the hillslope data management system. The effectiveness of training for other parties (e.g., private RPFs) and the potential variability/repeatability in their work are yet to be tested.

QA/QC, Statistical Analysis, and Data Management System

The hillslope data management system and the PMP hillslope data are currently in the process of being evaluated by statisticians under contract with CDF. Completing this work is necessary to: (a) draw more confident conclusions from the PMP hillslope component, and (b) allow LTMP data to be analyzed with the most appropriate statistical procedures. We may have more to learn about the feasibility and effectiveness of training, of field procedures, the database, and QA/QC for hillslope monitoring. At this point, it appears that it would be feasible to establish workable database links with the DFG instream component database.

Geologic Element

Evaluating fluvial geomorphology accurately enough to provide a helpful context for instream monitoring would require on-the-ground mapping in densely forested watersheds. Areas of hillslope geologic instability can be identified in forested watersheds, except where natural geologic features have been obscured by intense and/or repeated tractor yarding.

The hillslope component data have not yet been checked against the PMP geologic mapping to determine the degree of correlation between problems identified by hillslope monitoring and maps of erosional susceptibility. Once this is done, the cost-effectiveness and utility of similar geologic/geomorphic mapping for the LTMP can be assessed.

The results of the PMP mapping of erosional susceptibility was consistent with the results of the Erodible Watersheds Inventory.

The Erodible Watersheds Inventory may be an effective way to: (a) identify where more PMP-type geologic mapping would be warranted, and (b) stratify THP selection for LTMP hillslope monitoring.

Where pre-Rule logging roads, skid trails, and landings are extensive in or near streams and on steep slopes, they are the dominant factors controlling sediment yields.

Other Considerations

Timing of Monitoring

Restricting monitoring to once per timber operation does not allow evaluation of the effectiveness of Rule/BMP provisions over an extended time and/or under stressing events. This is especially important for rare but critical events such as gullying and shallow-seated landsliding. During the LTMP, a subset of the timber operations selected for hillslope monitoring should be re-evaluated following storm events with recurrence intervals of 5 years or more. The transect approach and/or the whole THP approach could be used for this purpose.

Restricting monitoring to after a timber operation is completed does not allow evaluation of the Rule/BMP provisions for which implementation can be evaluated only during a timber operation. An approach similar to the random transect approach could be used for this purpose during the LTMP.

Monitoring the Process

Poor Rule implementation was one major cause of water quality impacts reported by FPRAT (1987). The implementation monitoring approach tested to date allows evaluation of how good or poor Rule/BMP implementation is, but it does not allow evaluation of why it varies (i.e., the degree to which the Process and its various elements contribute to observed problems and/or good or poor implementation and effectiveness). An approach for doing this is yet to be developed and tested.

Nonstandard Practices

As indicated by frequent public criticism, FPRAT (1987), and CDF (1995), the effectiveness of nonstandard practices approved in a THP needs to be evaluated as part of the LTMP. Although hillslope monitoring forms include spaces for description of nonstandard practices and their effectiveness, a more complete evaluation approach was not developed during the PMP due to the difficulty in addressing their great variability, and PMP time and resource constraints. The approach cannot be Rule-driven as the tested approaches are, nor should it be entirely problem-driven. A whole THP survey may partially help to address nonstandard practices. An adequate approach is yet to be developed and tested.

Class III Watercourses

Despite its importance, MSG found no way to effectively evaluate sediment movement through Class III watercourses as part of a statewide monitoring program, especially where monitoring is conducted one time at randomly selected timber operations. It may require a research-level program that cannot be applied on a statewide scale.

Access to Private Lands

No problems accessing private lands were encountered during the PMP, largely because all PMP sites were located on the lands of cooperative timber industry companies and restricted to closed timber operations. Access may prove to be a problem in other situations, especially: (a) on small parcels of timberland, and (b) should trend or project monitoring sites need to be located away from a specific timber operation. As during the PMP, professional and industry organizations may be helpful in securing access, and access issues may need to be worked out on a case-by-case basis, especially for randomly selected timber operations.

CHAPTER IX.--LTMP ISSUES, OPTIONS, AND ALTERNATIVES

Introduction

This chapter addresses several issues, identifies options for changes, and concludes with three LTMP scenarios based on different funding levels. Issues involved in developing LTMP alternatives include the following:

a. Uses of LTMP information.
b. Quality of information needed to meet requirements of the intended uses.
c. Changes in the original intended uses due to technical and budgetary constraints.
d. Who is involved/conducting the monitoring work.
e. Funding.
f. How results are provided to BOF.
g. Coordination process that promotes adaptive monitoring.

Uses of LTMP Information

The LTMP is intended to do the following (MSG, 1993):

- Provide an ongoing assessment of the effectiveness of the Rules, as implemented, in protecting the most sensitive beneficial uses of water (i.e., coldwater fisheries and domestic water supplies) through implementation monitoring, effectiveness monitoring, and project monitoring.

- Provide the results to BOF and the public in a timely manner to contribute effectively to BOF's program for reviewing and, where necessary, strengthening the Rules' performance as BMPs.

The above intended uses can be further developed by considering the following potential uses of LTMP information.

Implementation Monitoring Results

These results could be used by CDF and BOF to:

1. Obtain feedback on how well the Rules/BMPs (or nonstandard practices) and the various elements of the Process are being carried out as a whole and individually.

2. Evaluate the effectiveness of the Process and its various elements in achieving intent statements, performance standards, and immediate objectives (e.g., minimize soil erosion and slope instability) set forth in the Rules.

3. Determine what refinements in the Process and its elements would be appropriate.

Effectiveness Monitoring Results

These results could be used by CDF and BOF to:

1. Obtain feedback on how well, as implemented, the various the Rule/BMP provisions (or nonstandard practices) are achieving their immediate objectives, both overall and under various environmental conditions.

2. Determine the relative importance, necessity, and effectiveness of the various Rule/BMP provisions in achieving intent statements and performance standards set forth in the Rules, both overall and under various environmental conditions.

3. Determine what refinements in the Rules/BMPs (including those providing for nonstandard practices) would be appropriate.

Project Monitoring Results

Should project monitoring results become available, they could be used by CDF and BOF to:

1. Obtain feedback regarding the observed changes in instream conditions near timber operations.

2. Determine the correlation between changes in stream conditions and environmental conditions related to quality of implementation, timber operations as a whole, and certain sets of Rules/BMPs or nonstandard practices.

3. Determine the relative importance, effectiveness, and necessity of various sets of Rules/BMPs and elements of the Process in protecting the quality and beneficial uses of water.

4. Identify appropriate refinements in the various Process elements, Rules/BMPs, and/or nonstandard practices.

Trend Monitoring Results

Trend monitoring results could be used by CDF and BOF to determine the degree to which:

1. Stream reach or watershed conditions are changing (either improving or degrading).

2. Cumulative effects are contributing to changes in coldwater fisheries or domestic water supplies in a watershed.

3. Increased watchfulness and/or protection measures are needed in a watershed.

4. There are correlations (across several watersheds, a region, or the State) between changes in watershed conditions, environmental conditions, quality of implementation, timber operations, other land activities, and (with project monitoring) certain sets of forest practices.

5. Watershed-based programs and BMPs designed to protect or recover beneficial uses of water are effective. These results can provide an important point of connection with other existing programs, industry-based monitoring efforts, and Clean Water Act Section 303(d) programs.

Quality of Information Needed

MSG (1993) states that the LTMP is intended to provide feedback needed to make informed management, policy, or regulatory decisions, not to provide evidence of a quality needed for legal or scientific purposes. Therefore, highest quality (level IV) information would not be needed. For some purposes, high quality (level III) information would be desirable to minimize uncertainty. For hillslope implementation and effectiveness monitoring, the random transect approach falls in the upper half of monitoring level II, and the whole THP approach falls near the boundary between monitoring levels I and II. The instream PMP parameters could be implemented at monitoring level III where suitable control stream reaches are available, but such controls are almost never available for typical timber operations.

Options for Changes

Where the desired levels of information are not attainable, changes in the LTMP should be considered. The options include the following: (a) limit the intended uses, (b) reduce the quality of information, but not the intended uses, (c) restrict the scale, intensity and/or focus of the LTMP, or some parts of it, (d) rely on monitoring by landowners and other parties, and/or (e) use other monitoring methodologies or strategies.

Limiting the Intended Uses

Possible options include the following:

1. Limit LTMP objectives to those achievable solely through hillslope monitoring.

   Focusing available resources onto hillslope monitoring (random transect approach and whole THP approach) would probably be feasible for state agencies (primarily CDF). This would provide much valuable information on BMP/Rule implementation and onsite effectiveness (see preceding discussions of potential uses of implementation and effectiveness monitoring information), but this will not directly determine the effectiveness of the Rules/BMPs, as implemented, in protecting the quality and beneficial uses of water. It also would not provide conclusive evidence regarding protection of fisheries and water quality. Project monitoring, where it is feasible, could be used to address this objective of the LTMP directly. Trend monitoring is the only way to directly address the issue of cumulative watershed effects, and, in some cases, it could indirectly address Rule/BMP effectiveness.

   The random transect approach does not directly address how well the intent statements and performance standards in the Rules are being achieved. The whole THP approach results may not be sufficiently accurate and reliable to provide a basis for changes in the Rules/BMPs or Process.

2. Limit LTMP objectives regarding the Process.

   Procedures for evaluating the effectiveness of the various elements of the Process have not been developed. Such procedures would allow determination of the reasons why implementation was either good or poor.

3. Limit LTMP objectives regarding nonstandard practices.

   Procedures for monitoring the implementation and effectiveness of nonstandard practices have not been fully developed. Such procedures are needed to address an area of the Process that generates the most criticism.

Limit the Information Quality, But Not the Intended Uses

If most interested parties participate in carrying out the LTMP, the quality of information provided by monitoring level II would probably be widely accepted. This option reduces the burden borne by any one party and can significantly reduce overall program requirements for expertise, equipment, personnel, and QA/QC. State agency coordination, training, oversight, and data management will still be needed. Issues involving access, use of results, and liability are yet to be resolved.

Restrict LTMP Intensity, Scale, and/or Focus

Reducing the number of sites monitored each year would be feasible and would reduce the annual workload. Accumulating a data set large enough to support statistically meaningful analysis would take longer.

Limiting LTMP sites to those in a given region or in certain watersheds is possible, either on an ongoing basis, or on an annually rotating basis. This would reduce the time and costs incurred by traveling to sites scattered around the State, but it would make it more difficult to avoid bias in the results, to confidently extrapolate results statewide, and to achieve the primary LTMP objective.

Monitoring could also be focussed on certain situations or practices that generate the most controversy or are considered strongly associated with water quality impacts. This approach would provide feedback regarding the particular situations, but its results and conclusions would have little applicability outside of the situations being monitored.

Monitoring by Others

In cooperation with the LTMP, monitoring may be done by individual landowners, multiple landowners, and landowners plus other interested parties. Monitoring by landowners with other interested parties has the greatest potential benefit at several levels. To protect the integrity of its LTMP monitoring data, monitoring information should be generated by trained persons following accepted protocols, and the State agencies should participate in QC oversight and auditing.

LTMP monitoring could be used to: (a) identify those key instream limiting factors for fish life cycle needs and key hazards that could be affected by timber operations, (b) conduct trend monitoring, (c) show the effectiveness of Rules/BMPs when they are well implemented, (d) test and carry out monitoring procedures for Rules/BMPs that can only be evaluated during conduct of an operation, (e) test and carry out monitoring procedures for Rule/BMP effectiveness under relatively infrequent stressing events, and (f) conduct initial testing and calibration of monitoring approaches for the whole THP approach and nonstandard practices. Issues involving access, use of results, and liability are yet to be resolved.

Landowner monitoring can be mandated for normal THPs only in exceptional circumstances. Relying on mandated monitoring for the LTMP would bias the results so severely that they may not be useful except as immediate feedback. The results would not provide a credible basis for BOF decisions affecting statewide or regional Rules/BMPs or the Process.

Contracting with others to carry out monitoring may be simpler for State agencies than redirecting staff. To the degree that persons who do not regularly prepare or review THPs (i.e., students, consultants, and local entities) are used, plan preparers and reviewers would be deprived of feedback that they may get through monitoring. This would defeat one important objective of the LTMP.

Interpreting and Using LTMP Information

The different users of the LTMP information will want to use the information in slightly different ways to reach different kinds of decisions. Thus, they are likely to need different capabilities for data access, queries, analyses, and reports. As keepers of the primary data, DFG and CDF will have central roles in determining the kinds of access, queries, analyses, and reports that will be structured into their data management systems, but they must be sensitive to the needs of other users.

It will be important to define what values of metrics, indices, ratings, or statistical test results are to be considered acceptable, which represent cause for concern, attention or study, and which represent conditions having a high priority for immediate change or remedy.

It is appropriate for MSG, in consultation with experts in data management and statistics, to review and recommend: (a) appropriate data management system capabilities to CDF and DFG, and (b) appropriate decision-making criteria and processes to BOF (and to CDF if so requested). It is also appropriate that an entity other than CDF or BOF be responsible for evaluating results and making recommendations to BOF. MSG or another standing BOF committee are reasonable options.

LTMP Alternatives for Three Funding Scenarios

Three funding scenarios for the LTMP have been considered in detail. They are: (a) no State agency funding, (b) continuance of current funding levels, and (c) full State agency funding for the LTMP. Other likely funding scenarios would be: (a) continuance of CDF funding at the current level, diminished DFG funding, and no SWRCB /RWQCB funding, and (b) same as above, but with SWRCB/USEPA 319 funding for monitoring in watersheds with management programs (e.g., 303(d) listed watersheds, sensitive watersheds, and/or SYP watersheds).

Three known factors affect the various alternatives. First, CDF expects to continue providing as much as $250,000/year for the LTMP, although the actual amount may often be somewhat less. Second, CDF tentatively plans to redirect 0.6 to 1.2 person-years from its existing audit program to hillslope monitoring. Third, the current DFG position is that: (a) regardless of funding level, it will not participate directly in any LTMP instream monitoring, and (b) it will only carry out training, QC oversight, data management, and further testing and validation of various instream monitoring parameterst if funded to do so. Currently, DFG's budget is being cut in all areas, so the most probable source of funding is via contracts with other agencies.

No State Agency Funding

The possibilities for hillslope monitoring (random transect only) in this alternative include the following, none of which are mutually exclusive: (a) hillslope monitoring by CDF inspectors during their normal inspections of timber operations, (b) hillslope monitoring by other CDF staff, and (c) hillslope monitoring by others. CDF inspectors could conduct hillslope monitoring during their completion inspections and/or during subsequent erosion control maintenance inspections (for one to three years following completion). CDF audit foresters could perform hillslope monitoring during the course of their field audits. These approaches would provide some immediate feedback to CDF regarding implementation and effectiveness of the Rules/BMPs. Other parties (e.g., landowners, Resource Conservation Districts) could also conduct hillslope monitoring if they are adequately trained and follow acceptable protocols.

However the hillslope monitoring data is generated, CDF would need to maintain a training and certification program, QC oversight, and the LTMP data management systems, as well as report LTMP data in an acceptable and timely manner. This could be accomplished by redirection of CDF staff.

With no State funding, any instream monitoring would be done entirely by other parties, and it would probably not include project monitoring. Therefore, it would be most likely to occur as part of private-sector monitoring programs, would not be randomly distributed, and may be very difficult to integrate (via instream project monitoring) with hillslope monitoring. All the CDF needs identified for hillslope monitoring in the preceding paragraph apply to instream monitoring except that DFG may be the primary affected agency. This effort could require about 1.5 person-years, but this would depend heavily on the degree landowner cooperation. As indicated above, DFG probably cannot carry out these tasks without additional funding.

This alternative would not allow for further LTMP development and testing by State agencies (e.g., whole THP survey, monitoring of the Process, and nonstandard practices). This would not preclude landowners from continuing to develop further monitoring approaches.

<u>Continuance of Current Funding Levels</u>

As indicated above, CDF expects to redirect about one person-year and continue providing as much as $250,000/year to the LTMP. This should be adequate to provide for the following:

1. CDF Tasks:

    a. About one CDF training session per year for private-sector and agency practitioners (not just trainers) of hillslope monitoring.

    b. Contract for about 50 hillslope monitoring THP evaluations per year.

    c. Up to 20 CDF QC oversight and auditing visits per year at sites where hillslope monitoring was conducted by others.

    d. Operation and maintenance of the CDF hillslope monitoring database with more complete and meaningful statistical analysis and reporting.

2. DFG Tasks (under contract to CDF):

    a. Conduct instream monitoring training and certification each year for private-sector and agency practitioners.

    b. Review of instream monitoring protocols and QC oversight and auditing site visits in watersheds where cooperative monitoring agreements exist for instream monitoring. (The actual monitoring would be conducted entirely by other parties.)

    c. Operation and maintenance of the DFG instream monitoring database with more complete and meaningful statistical analysis and reporting.

3. Joint Agency Tasks

   Development and testing of LTMP approaches and parameters, especially the whole THP survey, monitoring of the Process, and nonstandard practices.

4. Monitoring by Others

   a. Fund one or more cooperative monitoring watershed projects.

   b. Cooperate with ongoing landowner monitoring projects.

If SWRCB/RWQCB funding continues at its current level, they would continue to participate in LTMP development through MSG meetings and to manage any related 319 grant monies, but they would not participate in training, QC site visits, or independent monitoring.

Initially, the focus of both hillslope and instream monitoring will be on North Coast watersheds due the pressing importance of salmonid issues. Eventually, other areas of the State will be included. Instream monitoring would most likely occur only where private-sector monitoring programs exist, and it would probably not include project monitoring. Therefore, it would not be randomly distributed, and it may be very difficult to integrate with hillslope monitoring.

Full State Agency Funding

A full LTMP would have two primary components (Figure 4). One part would focus on watersheds where cooperative private-sector monitoring programs were being carried out; the other part would focus on randomly selected timber operations throughout the State. Ideally, there would be 5 or 6 cooperative monitoring watersheds scattered throughout the State's major timber-producing regions, and the watersheds would be fairly representative of those regions. The work in each watershed would resemble that described in the previous alternative. Random transect monitoring would be done at several (perhaps all) timber operations in each watershed. Instream monitoring parameters and approaches would be those found to be most relevant and feasible by a watershed assessment and would incorporate the recommendations in Rae (1995). Trend monitoring would be done at key points in the watershed where the probability of detecting relevant changes in the monitoring parameters was highest. These components would be integrated to maximize the ability to detect both site-specific and cumulative water quality effects of timber operations and trace those effects through the watershed.

BOF's commitment to iterative refinements of and additions to field monitoring techniques could be largely met by using cooperative monitoring watersheds for:

1. Testing, validation, and calibration of new approaches, including the following: (a) risk assessment approaches (to be used to stratify randomly selected timber operations), (b) disturbance indices for hillslopes and streams, (c) other instream monitoring parameters and protocols, (d) nonstandard practice monitoring, (d) Process monitoring, and (e) whole THP surveys;

2. Identifying significant correlations between water quality effects, environmental conditions, sets of forest practices, and implementation and/or effectiveness ratings (for example, comparison of areas where geologic mapping revealed slope stability problems and results of hillslope effectiveness monitoring); and

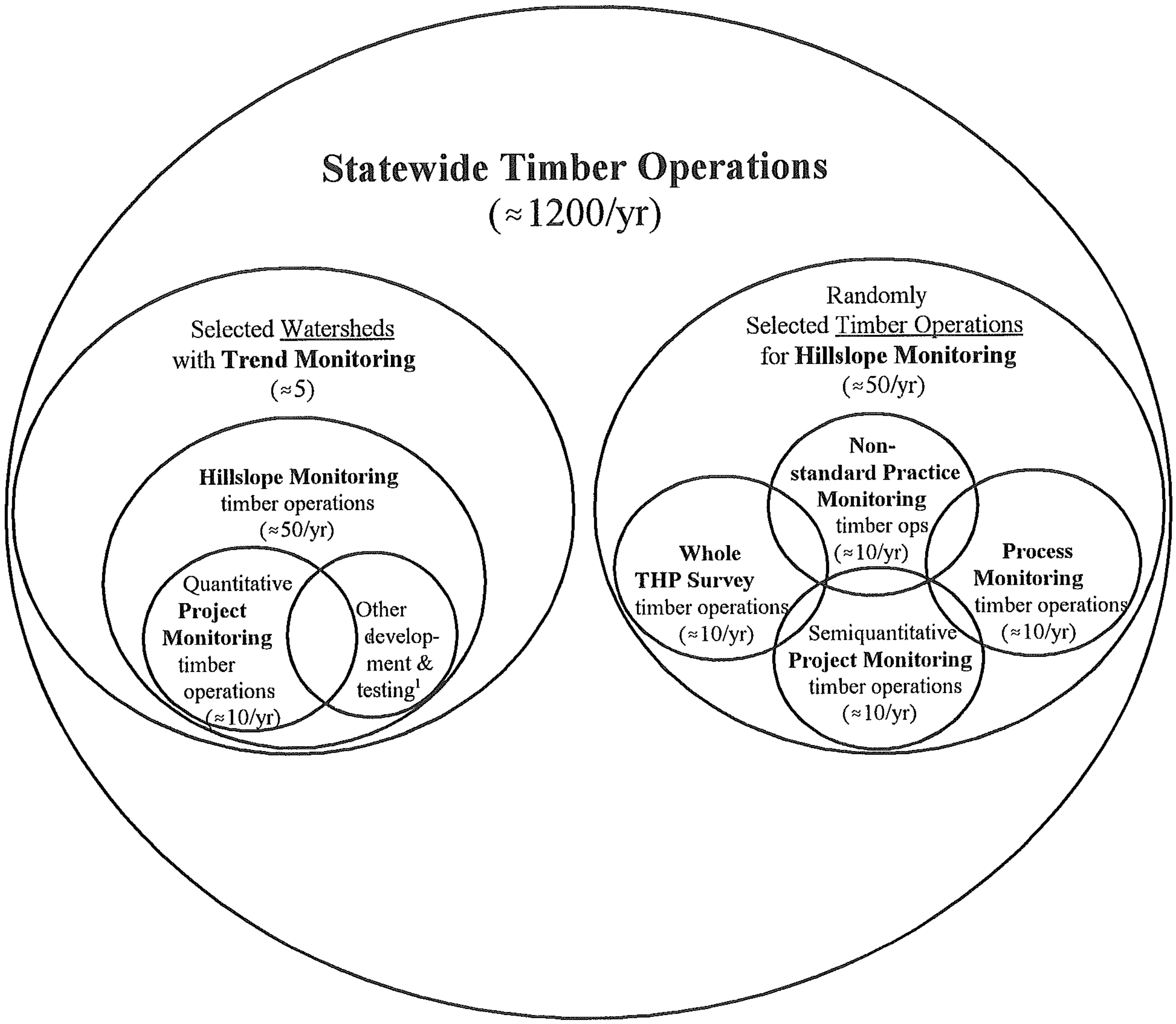
3. Identifying significant correlations between the results of differing monitoring parameters, protocols, and approaches. Examples could include statistical associations between: (a) the results of different hillslope monitoring approaches (i.e., random transect monitoring, whole THP surveys, Process monitoring, and nonstandard practice monitoring), (b) the results of different quantitative instream monitoring approaches (i.e., the PMP sediment-related parameters, macro-invertebrates, and temperature), (c) the results of semi-quantitative/ categorical instream monitoring and of quantitative instream monitoring, and (d) the results of hillslope monitoring and of quantitative and/or semi-quantitative/categorical instream monitoring. Finding significant correlations could have several benefits for the LTMP. For example, it could allow the substitution of a more simple, less costly monitoring approach for a more complex and costly approach, or it might allow meaningful use of hillslope monitoring results as surrogates for instream project monitoring results.

State agencies would work with landowners and other interested parties to select, develop, test, and calibrate each approach. Once validated and calibrated, whole THP surveys, monitoring of the Process and nonstandard practices, and other instream monitoring approaches would be integrated with the other components of watershed monitoring. Monitoring and other work could be done primarily by the landowner (hopefully with participation by other interested parties) with State agency training, oversight and audits, and in accordance with State-agency approved parameters and protocols.

In addition, a subset of monitored timber operations could be revisited to facilitate evaluation of Rule/BMP effectiveness over a long term and/or under stressing climatic events in cooperative monitoring watersheds and elsewhere.

Outside of cooperative monitoring watersheds, CDF would be the lead agency for carrying out random transect monitoring at about 50 randomly selected timber operations each year. As in previous alternatives, some monitoring could be conducted by other parties with State agency training, oversight, and auditing. In addition, after being appropriately validated and calibrated in the cooperative monitoring watersheds, CDF and/or other parties would carry out any one or more of the following approaches at a subset (about one fifth) of these timber operations: (a) a whole THP survey, (b) Process monitoring, and/or (c) nonstandard practice monitoring. No quantitative instream trend monitoring or project monitoring would be carried out at these timber operations. However, if statistical associations are found in the cooperative monitoring watersheds between results of quantitative instream monitoring and the results of random transect monitoring, and/or whole THP surveys, it may be possible to extrapolate these associations for use elsewhere in a timber-producing region. If so, the hillslope monitoring results from timber operations scattered around the State may serve as surrogates by which the effectiveness of the Rules/BMPs, as implemented, can be estimated for the State as a whole. This could allow the original primary objective of the LTMP to be met without widespread use of quantitative instream monitoring.

Figure 4. Diagram of LTMP



[1] Other development and testing in monitoring watersheds may include the following: (a) risk assessment for stratification of random selection process, (b) hillslope and stream disturbance indices, (c) solar pathfinder stream insolation, (d) semi-quantitative instream monitoring, (e) nonstandard practice monitoring, (f) Process monitoring, and (g) whole THP survey.

CHAPTER X.--CURRENT MSG RECOMMENDATIONS FOR THE LTMP

General Program Recommendations

1. The LTMP is valuable and should be continued.

2. The instream monitoring approaches and protocols being used in forested watersheds by the private sector and USFS should be periodically reviewed and evaluated to determine: (a) their utility, range of applicability, and potential for being used elsewhere in the present watershed and in other watersheds, (b) their capability for generating data that are of sufficient quality and that are compatible with other LTMP data sets.

3. Cooperative watershed monitoring projects, including instream trend monitoring, should be pursued.

4. The PMP random transect procedure should be carried out by trained personnel under direct RPF supervision at randomly selected timber operations with CDF providing training, reference materials, oversight, and QC auditing.

5. CDF and DFG should further develop their monitoring databases to facilitate LTMP data analysis, reporting, and accessibility.

6. Other instream and hillslope monitoring procedures should continually be developed and tested.

7. The BOF should continue pursuing their February, 1995 LTMP commitments.

Discussion

The LTMP could be integrated, where appropriate, with a number of other programs to realize greater efficiencies. For example, long-term monitoring is an important aspect of multispecies Habitat Conservation Plans to address impending listings of several salmonid and other species under the Federal Endangered Species Act. Additional situations where the LTMP could provide benefits include: 1) watersheds with ongoing litigation regarding THP environmental review, and 2) impaired waterbodies with Total Maximum Daily Load (TMDL) requirements pursuant to the Federal Clean Water Act. Given these conditions, MSG has the following general recommendations:

1. As these government and legal requirements become clear:

   a. MSG should reconsider the LTMP, its objectives and approaches, and make recommendations for changes to the long-term program; and

   b. The BOF commitments should be more aggressively pursued and elevated if necessary through the Resources Agency and the California Environmental Protection Agency.

2. Until that time, the LTMP will continue under current agency funding levels, as described under the second alternative for the long-term program presented in the previous chapter.

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GLOSSARY

Accuracy -- The degree of agreement between a measured value and the true or expected value for the parameter.

Beneficial use(s) of water -- According to the Porter-Cologne Water Quality Control Act, the beneficial uses of water include, but are not limited to: domestic, municipal, agricultural, and industrial supply; power generation; recreation; aesthetic enjoyment; navigation; and preservation and enhancement of fish and wildlife, and other aquatic resources or preserves. In Water Quality Control Plans, the beneficial uses designated for a given body of water typically include the following: domestic, municipal, agricultural, and industrial supply; industrial process; water contact recreation and non-water contact recreation; hydropower generation; navigation; groundwater recharge; fish spawning, rearing, and migration; aquatic habitat for warm-water species; aquatic habitat for coldwater species; and aquatic habitat for rare, threatened, and/or endangered species.

Best management practice (BMP) -- A practice or set of practices that is the most effective means of preventing or reducing the generation of nonpoint source pollution from a particular type of land use (e.g., silviculture) and that is feasible, given environmental, economic, institutional, and technical constraints. Application of BMPs is intended to achieve compliance with applicable water quality requirements.

Categorical -- A system of measurement or ranking in which the values allowed for a parameter can fall only into discontinuous predefined categories. For example, the allowed values for implementation in the random transect approach for hillslope monitoring can be only 1, 2, 3, 4, 5, 0, or NA; no intermediate values are allowed. This contrasts with a continuous system of measurement.

Comparability -- A non-quantitative measure of the confidence with which one data set can be compared to another.

Completeness -- The percentage of measurements made that are judged to be valid.

Control -- Results that are: (a) from one or more stream reaches unaffected by the project being monitored, (b) used as a standard against which the results of project monitoring may be compared, and (c) necessary to distinguish instream changes due to the project from those due to other environmental or land management factors. A temporal control enables before/after comparisons; it comprises results from monitoring done (usually at the project stream reach) before a project is initiated. A spatial control comprises results from monitoring done at a control stream reach, usually concurrently with the monitoring being done in the project stream reach.

Control stream reach -- A stream reach monitored to provide a spatial control for project monitoring. It must be very similar to the project stream reach (to reduce the amount of variability from extraneous factors) and located either (a) upstream from the project stream reach (upstream/downstream comparison), or (b) on a different stream (paired approach).

Data management system -- A system, including electronic and hard copy files and related QA/QC protocols, for entering, validating, correcting, storing, retrieving, transferring, analyzing, and reporting monitoring data in a manner which will provide timely and reliable results and meaningful information for decision-makers.

Feature -- In the random transect approach for hillslope monitoring, any constructed feature along a landing, road, skid trail, or watercourse crossing (e.g., cut bank, fill slope, inside ditch, cross drain, water bar).

Monitoring parameter -- The variable being studied by sampling, observation, or measurement.

Nonpoint source -- A widely distributed land management activity (e.g., silviculture, mining, agriculture, grazing) generating pollution that: (a) has no readily apparent point of discharge, and/or (b) cannot be controlled by collection and treatment.

Nonstandard practice -- A practice other than a standard practice, but allowable by the Rules as an alternative practice, in-lieu practice, waiver, exclusion, or exemption.

PMP parameter -- A quantitative instream monitoring parameter tested during the PMP.

Precision -- A measure of mutual agreement among individual measurements or values of a monitoring parameter taken under similar conditions.

Problem -- In the random transect approach for hillslope monitoring, the occurrence of: (a) rilling, gullying, or landsliding found along landings, roads, skid trails, or watercourse crossings, and (b) shade loss or streambank erosion along a watercourse.

Process -- The process by which the Rules/BMPs are administered and implemented, including: (a) the process elements for THP preparation, information content, review and approval by RPFs, Review Team agencies, and CDF decision-makers, and (b) the process elements for timber operation conduct, inspection, and completion by LTOs and CDF inspectors.

Project stream reach -- The stream reach monitored to detect the effects of a project.

Protocol -- A set of exact specifications and work procedures for any part of a monitoring program, including: (a) preparing, calibrating and maintaining equipment and supplies, (b) data and sample collection/entry, handling and transfer; (c) laboratory and statistical analysis; (d) data management and interpretation; (e) detecting data defects; and (f) taking corrective actions.

Qualitative -- a narrative, nonnumeric method of description.

Quality assurance (QA) -- The steps taken to ensure that a product (i.e., monitoring data) meets specified objectives or standards. This can include: specification of the objectives for the program and for data (i.e., precision, accuracy, completeness, representativeness, comparability, and repeatability), minimum personnel qualifications (i.e., education, training, experience), training programs, reference materials (i.e., protocols, instructions, guidelines, forms) for use in the field, laboratory, office, and data management system.

Quality control (QC) -- The steps taken to ensure that products which do not meet specified objectives or standards (i.e., data errors and omissions, analytical errors) are detected and either eliminated or corrected.

Quantitative -- A method of measurement using a continuous set of numbers in which the values allowed for a parameter can be infinitely precise (e.g., they can include decimal fractions)..

Repeatability -- The degree of agreement between measurements or values of a monitoring parameter made under the same conditions by different observers.

Representativeness -- The degree to which a monitoring parameter or data accurately and adequately represent a characteristic of a population, variations at a sampling point, or an environmental condition.

Rules/BMPs -- Those Rules that are related to protection of the quality and beneficial uses of water and have been certified by the SWRCB as BMPs for protecting the quality and beneficial uses of water to a degree that achieves compliance with applicable water quality requirements.

Semi-quantitative -- A method of measurement using discrete or discontinuous numbers into which observations or estimations are ranked.

Source-search -- Tracing an observed plume of pollution to its source.

Standard practice -- A practice prescribed or proscribed by the Rules.

Statistical association -- The degree to which values for a dependent variable correlate with values for one or more independent variables as determined by any of several statistical tests.

Stream reach -- A portion of a stream channel defined throughout its length by a set of hydrologic and geomorphic conditions (e.g., gradient, sinuosity, depth/width ratio, pool/riffle/run ratio) that: (a) are fairly uniform, and (b) differentiate it from upstream and downstream portions of the stream channel.

APPENDIX

SUMMARY OF CDF MONITORING CONTRACTS RELATED TO THE PILOT MONITORING PROGRAM AND THE LONG-TERM MONITORING PROGRAM

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Introduction

The California Department of Forestry and Fire Protection (CDF) produced the following contracts to support the Long-Term Monitoring Program (LTMP). Initially, information was collected on the two most sensitive beneficial uses of water, cold water fisheries habitat (Knopp) and domestic water sources (Chakraborty). Additionally, an inventory was made of the inherent erodibility of watersheds with private timberlands throughout California (Spittler and McKittrick). This information will be used with hillslope monitoring in the LTMP to determine Rule performance in higher risk watersheds. Contracts were developed to further refine our knowledge regarding promising sediment monitoring techniques, including V* (Lisle, Lydgate) and RASI (Dresser). We also attempted to relate biological indicators to previously studied physical instream channel parameters (Pogue). Finally, we supported research on road stream crossings to develop better methodologies for stream crossing evaluation techniques, an important component of watershed assessment and monitoring (Trush). Although these contracts were not directly a part of the Pilot Monitoring Program, they were conducted concurrently, and provided some of the lessons which were learned during the PMP time frame.

Erodible Watersheds Inventory

Tom Spittler and Mary Anne McKittrick
Department of Conservation, Division of Mines and Geology

The California Department of Conservation, Division of Mines and Geology completed this project to map the inherent erosion hazard for watersheds (30,000 to 50,000 acres) with both significant private holdings and commercial timberlands. Planning watersheds were combined to form larger "super" planning watersheds for this analysis. Maps were produced rating surface erosion, landsliding, debris sliding, and total erosion potential. A Geographic Information System (GIS) model was used to estimate the degree of erosion potential for each of the various categories studied. Data layers included slope, precipitation intensity (50-year 2-hour and 12-hour), and geology. U.S. Geological Survey digital elevation models were used for the slope parameter. The geology of the areas included in the project was digitized from a 1:750,000 scale geologic map of California. Qualitative evaluations of geologic material strength were developed from personal interviews with professional geologists with extensive experience in northern California. In each large watershed, the physical attributes of slope, precipitation, and geologic susceptibility to failure were stratified into low, moderate, and high categories. Rated polygons were area-weighted and a simple, linear additive relationship was used to combine data sets. The use of the additive data combination produces an array of ranked watersheds depicting those basins which are theoretically most susceptible to accelerated hillslope erosion. The GIS data layer for this project is located on CDF's Fire and Resource Assessment Program (FRAP) computer system in Sacramento. These maps will help the LTMP in determining overall erosion hazard in various parts of the state.

Inventory of Potentially Impacted Drinking Water Supply Systems in California

Dave Chakraborty, Consultant

This project mapped and recorded information on permitted community domestic water supplies (5-200 connections) located within or downstream of watersheds with private, state, and federally owned commercial timberlands in California. Only those systems that utilize surface flow from creeks/springs, or those using wells that tap the underflow of a stream were entered into the database. Data collected included type of system, owner, number of connections, type of filtration, storage capacity, intake location, documented problems with the system, and principle timberland owners within the watershed. Water supplies were mapped on 7.5 minute topographic maps, which were subsequently digitized into an ArcInfo GIS layer at CDF's FRAP office in Sacramento. A database utilizing Microsoft Access for Windows was developed for the water supplies in 34 counties in California. Data was collected from county health departments, the California Department of Health Services-Office of Drinking Water Supply, and surveys of individual water purveyors. Domestic water sources are one of the most sensitive beneficial uses of water and must be considered in the LTMP.

Testing Indices of Cold Water Fish Habitat

Chris Knopp, U.S. Department of Agriculture, Forest Service (USFS)

Working for the North Coast Regional Water Quality Control Board, Mr. Knopp completed a study to quantify the condition of cold water fish habitat within the North Coast Planning Basin of California. Sixty stream reaches within one geologic type (Franciscan sandstone/shale) were sampled. Three parameters measured showed significant differences between reaches with varying levels of upslope disturbance: 1) V*, the ratio of the volume of fine sediment in a pool to the scoured volume of the pool, 2) riffle armor stability index (RASI), an index of the relative size of the largest riffle bed particles that moved during the most recent bankfull flows, and 3) D_{50}, the median particle size of the riffle gravels. Stream reaches with only historic logging (i.e., 40 to 80+ years ago) exhibited habitat values that were statistically indistinguishable from the reaches with recent logging. Therefore, streams are slow to recover due to storage of residual sediment generated from the initial logging. These variables can be used to evaluate current channel condition and changes over time (i.e., trend monitoring).

Development of Fine-Sediment Volume in Pools as a Method to Monitor and Evaluate Sediment Effects on Northern California Streams

Dr. Thomas Lisle, USFS, Pacific Southwest Research Station

Dr. Lisle has found that as the supply of sediment increases in a channel, fine sediment is concentrated in pools during low flows. V* was developed to be an index of channel condition to evaluate cumulative effects so that unacceptable degradation of fish habitat can be avoided. Twenty-four reaches of streams in northern California and southern Oregon were added to the original set of eight studied by Lisle in 1992. Basins were chosen to include a variety of rock types and disturbance histories. Geologic types that produce moderate to high concentrations of fines (e.g., Franciscan and other soft or sheared sediments, weathered granite, schist) produce high background values of V* and show a strong response to sediment yield. In contrast, geologies with competent rocks (high grade metamorphic rocks of the Klamath Mountains, basalt, competent sandstone) produce low V* values and show a weak response. V* values for a channel should be interpreted by comparison with values from control (undisturbed) basins with the same lithology. The report submitted to CDF concludes that V* is a sensitive index of the supply of mobile sediment in geologic types that produce moderate to high fractions of fines.

Measuring the Effects of Increasing Loads of Fine Sediment on Aquatic Populations of *Dicamptodon tenebrosus* (Pacific Giant Salamander) on California's North Coast

Seth Pogue, Graduate Student, Humboldt State University

As part of a master's thesis, Mr. Pogue remeasured 49 of the stream reaches utilized by Knopp (see summary above). Pacific Giant Salamander biomass, density, and size class composition were compared with RASI and D_{50} in an effort to generate a suitable biological indicator of habitat condition. This study provided an opportunity to test whether biological productivity of aquatic habitat is adversely affected by increasing loads of channel sedimentation. A steady decline in biomass and number of surviving size classes was observed with decreasing riffle stability. The study demonstrated that two measures of *D. tenebrosus* population parameters - biomass/m^2 and size class composition - can be used as tools for accurate, repeatable measure of aquatic habitat condition. This animal appears to be a good candidate as a biological monitoring tool that can provide for the assessment of instream conditions with respect to various types of land uses.

Fine Sediment in Residual Stream Pools: Temporal and Spatial Consistency of a Measuring Technique

William Lydgate, Graduate Student, Humboldt State University

Similar to Mr. Pogue, Mr. Lydgate remeasured 28 stream reaches utilized by Knopp (see summary above). The repeatability of V* as a measurement technique was tested by analyzing annual variation in 144 paired pools over a two-year period. Measurements from the first year followed five years of below normal rainfall. The following year's measurements were taken after a near normal water year with bankfull discharges. Of the 28 streams remeasured, 15 had low V* values reported from the first year and 13 streams had high v-star values. Results suggest that annual variation is equal to or less than measurement error. V* values for a given stream reach (V^*_w, or the average of all the pools measured weighted by pool volume), was found to be stable for both low and high V* streams, despite V* fluctuations in individual pools. Low V* variation between water years suggests that a wet winter, even following a long drought, does not significantly alter V*. This parameter appears to be a stable method for rating watershed condition.

An Evaluation of Two Measures of Streambed Condition

Adam Dresser, Graduate Student, Humboldt State University

This master's thesis evaluated two methods for quantifying streambed condition: a dimensionless bedload transport ratio called "q*", and RASI. The study site was Little Lost Man Creek in Redwood National Park, a low-sediment, nearly pristine stream with a coarse, heavily armored streambed. Problems were noted for both of these two parameters. The selection process for the 30 clearly mobile particles on a riffle needed to calculate the RASI index requires refinement to reduce investigator bias. RASI may be useful when combined with other stream assessment techniques such as V*, but the variance between sampled reaches in Little Lost Man Creek was too high to provide reproducible estimates. While q* may have a better theoretical background than RASI, results from this field site indicated that sample variance was sensitive to site selection. Also, q* involves intensive field work and is very time consuming. It may not apply to streams with a coarse bed or with bedrock controls.

Road Stream Crossings: Design, Construction, Maintenance, and Restoration to Reduce Costs and Environmental Risk

Dr. William Trush, Institute for River Ecosystems, Humboldt State University

While Dr. Trush's project is yet to be fully completed, he and several graduate students have gathered data throughout the North Coast area which will yield a considerable amount of new information for resource professionals who design and evaluate stream crossings in California. Specific goals include: 1) developing basinwide stream crossing evaluation techniques, which is a very important component of an assessment of watershed condition; 2) testing flood prediction methodologies; 3) improving design criteria; 4) minimizing replacement criteria; and 5) reducing environmental impacts such as erosion and fish migration blockage. Brief summaries of some of the studies conducted for this project follow.

Culvert Rustline-Exceedence Probability Investigation: North Coast Region of California

George Donohue, Graduate Student, Humboldt State University

This study attempted to find a simple field method for determining which culverts should be carefully evaluated for sizing when doing a watershed inventory (as it is too burdensome to do this for all crossings in a basin). The internal zone of corrosion, or the "rustline" was chosen for this study. Specifically, the project determined whether culverts with a high rustline would be able to pass the design flood. Discharges corresponding to the rustline were calculated with Mannings Equation. The relationship between rustline discharge was then compared to the mean daily flow of a given exceedence probability. Regionalized daily average flow duration curves were created, so that it was possible to plot the cumulative percentage of time flow is equaled or exceeded against a particular rustline discharge. The preliminary results show that the majority of rustline discharges fall below 6% exceedence probability, or alternately, that for an appropriately sized pipe, 6% of the time flow exceeds the rustline discharge. If the rustline is much higher, the pipe is probably undersized and the pipe needs to be carefully evaluated. This appears to be a cost-effective methodology to assess corrugated metal pipes.

Woody Debris Transport Through Low Order Stream Channels - Implications for Stream Crossings

Sam Flanagan, Graduate Student, Humboldt State University

Culvert crossing design currently addresses flow but usually does not consider woody debris capacity, even though it is often the dominant cause of failure. This project investigated woody debris transport dynamics as a function of active channel width and interaction with culverts. Debris screens were installed below 26 culverts. About 98% of the wood transported through the culverts was shorter than the active channel width. The size of debris moved was less sensitive to drainage area than was previously thought. Sizing culverts by mean active channel width can simultaneously allow for passage of wood and peak flows. For example, at one site culverts sized at 70% active channel width passed 95% of woody debris.

A Comparison of Empirical and Regional Peak Discharge Prediction Accuracy for a January, 1995 Northwestern California Rainfall Event

Todd Buxton, Sam Flanagan, and William Trush, Graduate Students and Professor, Humboldt State University, respectively

This project investigated the discharge prediction accuracy of methods commonly used in the Northwestern region of California for culvert installation and capacity evaluation. Two empirical and seven regional flow prediction methods were evaluated. Measured discharge was compared to predicted discharge at 15 Bull

Creek tributaries. Peak discharge was recorded with clay applied to the pipe circumference during the previous summer. Results showed considerable disagreement between the various methods. The difference between extreme over and under predictions was 667%. Prediction equations derived by Northern California regional data either over predicted or predicted near the actual discharge. Overall, evaluated regional equations outdid empirical equations in accuracy.

A Methodology for Basinwide Evaluation of Stream Crossings for Peak Discharge, Woody Debris, and Fish Passage

Todd Buxton and George Donohue, Graduate Students, Humboldt State University

This project is developing a methodology that addresses all of the significant aspects of culvert design. Recommended field measurements will provide an analysis of a culvert's expected performance. Techniques will integrate the information gathered in previous work completed for this project, and will include: 1) rustline exceedence discharge, 2) headwater depth to diameter ratio (HW/D) and relation to active channel width for large woody debris transport, 3) discharge capacity and relation to recurrence interval, and 4) fish passage capabilities. Methodologies will emphasize quick, accurate field methods that address the full range of culvert related concerns.